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The Golden Eagle: Its Status, Conservation, And Management in 1999

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DEDICATION

J. Raptor Res. 36(1 Supplement):1

Walter Spofford earned his living as a professor of anatomy, but had a lifelong passion for birds of prey. An early survey by Walter helped to curb the pernicious practice of shooting eagles from aircraft. In later years, he annually surveyed and studied the few scattered pairs of Golden Eagles nesting in the northeastern United States. On one such occasion, he took the late Leslie Brown and me to former nest sites in the Adirondacks of New York. After Walter and wife Sally moved to Arizona, they were in true eagle country. I recall toiling up a mountain slope with "Spoff" as he sought a secure place to set free a young eagle he had nursed back to health and vigor.

Walter's most lasting legacy may well prove to be the unstinting encouragement he gave to young students of raptors. On the last occasion I was in the field with him, he drove out of his way to pick up two chaps who were eager to share a field trip with him. He was equally thoughtful in making his data available to authors. The account of the Golden Eagle in Palmer's volumes on American raptors contains many items sent to him by Spoff. Always, his wife, Dr. Sally Spofford, a published ornithologist in her own right, was at his shoulder with her insights and indispensable support.

What an appropriate gesture to dedicate this volume on the Golden Eagle to that devoted "raptorologist," Walter Spofford.—**Dean Amadon, Lamont Curator of Birds, Emeritus, American Museum of Natural History, New York, NY 10024 U.S.A.**

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PREFACE

STATUS AND CONSERVATION OF GOLDEN EAGLES

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The Golden Eagle (*Aquila chrysaetos*) is a cosmopolitan species occurring on every continent of the Northern Hemisphere and locally in northern Africa (Palmer 1988, Kochert et al. 2002). It is found widely across Europe and Asia where its current numbers are largely unknown but, in most countries, it is considered to have declined. In the British Isles, for instance, its numbers have been greatly reduced (Watson 1997) and, in Japan, it is rare and listed as an Endangered Species (M. Abe pers. comm.). In North America, the Golden Eagle historically inhabited much of the continent. Today, it has essentially been eliminated from most eastern states but populations throughout Canada and the western U.S. are considered to be abundant and stable. In Mexico, very little information exists on the species' status. The Golden Eagle is officially listed as Threatened or Endangered in most countries included within its range and its status in many other countries is uncertain (Kochert et al. 2002).

There have been several documented threats to Golden Eagle populations. Shooting has been a serious threat throughout the range of the species, especially where it has come into contact with livestock (Palmer 1988). Poisoning, both intentional and unintentional, has also been a problem. Intentional poisonings have resulted from efforts to control predators in areas where eagles have been suspected of depredating livestock (Watson 1997). Unintentional poisonings have been associated with environmental contaminants such as lead and organochlorine contaminants. More recently, afforestation and human disturbances in nesting areas have been cited as threats to Golden Eagles (Watson 1997).

Because of the need for more information on the current status of the Golden Eagle and threats that jeopardize its future survival, a symposium was organized as part of the 1999 annual meeting of the Raptor Research Foundation held in La Paz, Mexico. Its purpose was to bring together currently-active researchers from all regions of the Golden Eagle's distribution to give first-hand information on the distribution and status of the Golden Eagle in their region. Together, these papers represent a synthesis of the current state of knowledge and conservation status of Golden Eagles in several locations around the world. They give information on distribution, breeding behavior, habitat requirements, prey needs, and sensitivity to habitat modification, which can be used to direct future research on the conservation of this species.

Acknowledgments

The symposium was sponsored by the Raptor Research Foundation, Inc., Centro de Investigaciones Biológicas del Noroeste, S.C., Fundación ARA, A.C., and Maca Romo. The publication of these proceedings was funded by Sally Spofford.

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A SURVEY OF GOLDEN EAGLES IN NORTHERN MEXICO IN 1984 AND RECENT RECORDS IN CENTRAL AND SOUTHERN BAJA CALIFORNIA PENINSULA

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ABSTRACT.—Results of a Golden Eagle (*Aquila chrysaetos*) survey in the states of Coahuila, Durango, Zacatecas, Chihuahua, and Sonora in 1984, and records of eagles in the southern portion of the Baja California peninsula are presented. Results showed that Golden Eagles were common in all northern states of Mexico and in southern Baja California peninsula. Although most were found in sierras with oak-pine forest vegetation and valleys with grasslands, Golden Eagles were also found to be common in xerophytic scrub vegetation. In Baja California Sur, Golden Eagles were recorded in sierras and valleys with oak-pine forest, but more frequently in xerophytic scrub vegetation. We found old nests that were probably constructed by Golden Eagles, but no actual breeding activity was recorded in the state of Baja California Sur. More studies should be done in order to understand the trends of Golden Eagle populations in Mexico. The Golden Eagle National Recovery Plan supports the idea that long-term studies on Golden Eagles in Mexico should be done to better understand the factors affecting populations on the local and regional scale.

KEY WORDS: *Golden Eagle*; Aquila chrysaetos; *Coahuila*; *Durango*; *Zacatecas*; *Chihuahua*; *Sonora*; *Baja California peninsula*; *Mexico.*

Monitoreo de águila real en el norte de México (1984), y algunos registros recientes del centro y sur de la península de Baja California

RESÚMEN.—Se presentan los resultados de un recorrido por los estados norteños de Coahuila, Durango, Zacatecas, Chihuahua y Sonora, México realizado en 1984 buscando águila real. Asimismo, se presentan los resultados de los registros de águila real en la península de Baja California. Las águilas fueron encontradas principalmente en sierras con bosque de encino-pino y en valles con pastizales, aunque también fueron comunes en la vegetación de matorral xerófilo, habiéndose registrado en 18 localidades en Coahuila, 17 en Durango, 16 en Chihuahua, 13 en Zacatecas y 5 en Sonora. En Baja California Sur fueron especialmente frecuentes los registros en el área del desierto de El Vizcaíno y en Sierra de la Laguna. En Baja California localizamos algunos nidos viejos probablemente construídos por águilas reales, sin embargo no hemos sido capaces de localizar parejas reproductivas. Aunque la información para el norte de México es de 1984, puede servir para darnos una idea de la situación de las poblaciones de águila real en aquel periodo. Esta información podría ser contrastada con la situación actual si se hiciera un muestreo similar ahora. En la actualidad no es posible entender las tendencias de las poblaciones de águila real en México debido a que no existe información ubicada de manera temporal que lo permita. El Plan Nacional de Recuperación del Aguila Real de México promueve en su estrategia la realización de estudios a largo plazo del águila real como una manera de entender los factores que afectan sus poblaciones en una escala local y regional.

[Traducción del autor]

The Golden Eagle (*Aquila chrysaetos*) has been studied very little in Mexico and, at the present, little published information exists (Watson 1997). In the 1950s, the Golden Eagle occupied an extensive range in the country from northern to central Mexico, and once was reported in the valley of Mexico (e.g., Mexico City). At present, its distribution has been reduced as the burgeoning Mexican population has encroached on its preferred habitats; however, the extent of the decline in the population in Mexico remains unknown. In central Mexico, the Golden Eagle is now recorded in the states of Zacatecas, Aguascalientes, San Luis Potosi, and Jalisco and it is still widely distributed in north-

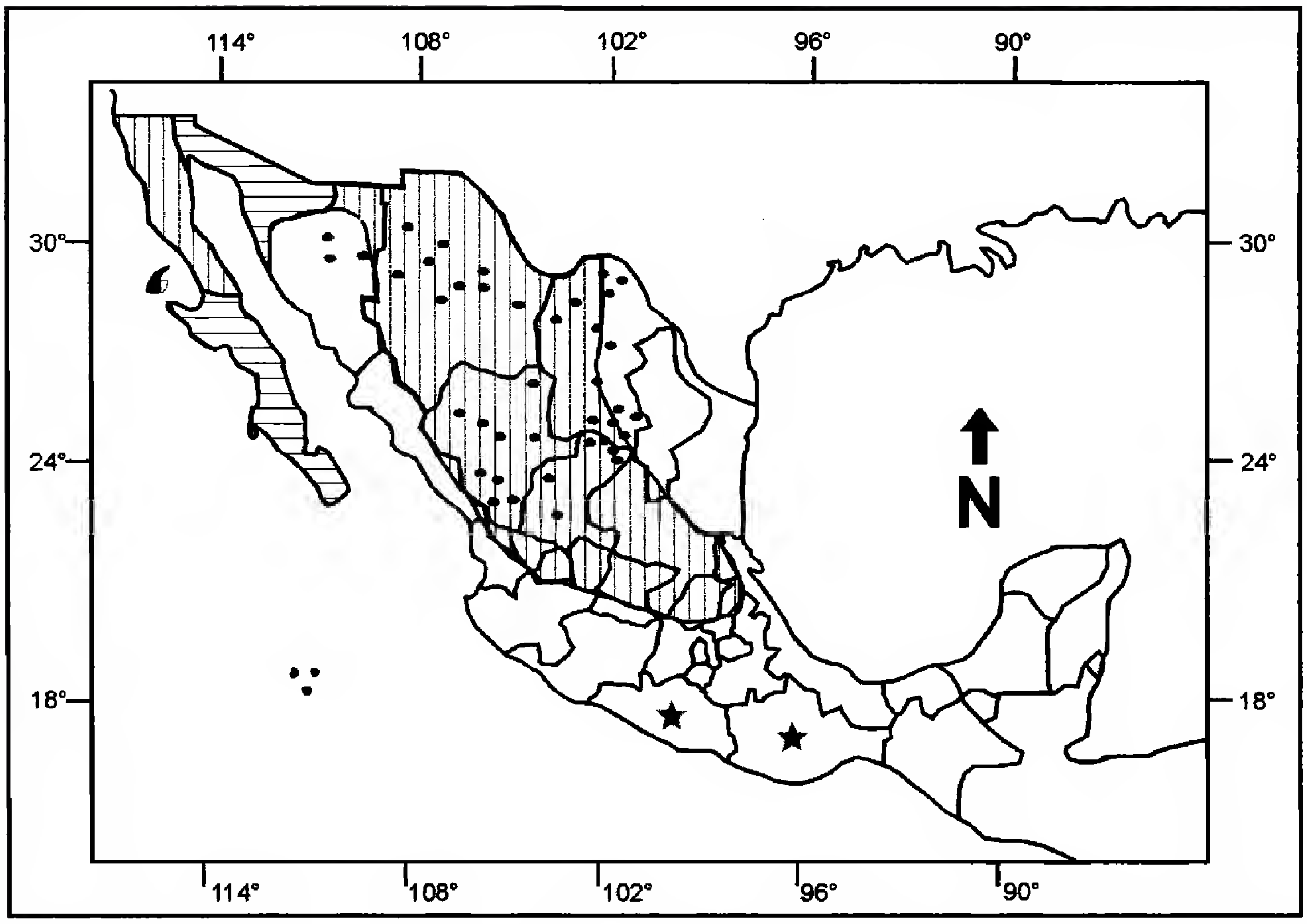

Figure 1. Golden Eagle records (points) in northern Mexico obtained during the 1984 survey. Hatched areas show the Golden Eagle distribution according to Howell and Webb (1995). Museum records of Oaxaca and Guerrero are marked with a star (Ramírez-Bastida and Navarro pers. comm.).

ern Mexico, particularly in remote areas where eagles may nest in the absence of human disturbance.

In 1984, we made the first national Golden Eagle survey in northern Mexico to determine the actual and potential range of the resident breeding population (Rodríguez-Estrella and Nocedal 1985). Although this study was made over an extensive area in a short period of time, the results we obtained give a general idea of the status of the Golden Eagle in 1984 in northern Mexico. Our technical report was the first document used by federal agencies to establish priorities for Golden Eagle conservation. In addition, after our report was published, local studies in several states of Mexico began to determine more precisely the regional status of the Golden Eagle, a species that is listed as Endangered in Mexico (NOM-059, Diario Oficial de la Federación 1994). Herein, we report the results of the 1984 Golden Eagle survey and the records of Golden Eagles in the southern portion of the Baja California peninsula. Our goal is to contribute to the knowledge of the ecology and distribution of the Golden Eagle in Mexico.

STUDY AREA

The study was conducted in the states of Coahuila, Durango, Zacatecas, Chihuahua, and Sonora, and the Baja California peninsula (Fig. 1). Surveys were made in sierras with valleys and canyons. Predominant vegetation was oak (*Quercus* spp.) and oak-pine (*Pinus* spp.) forests in elevated sierras and canyons, xerophytic scrub vegetation in low sierras, valleys, and canyons, and grasslands in valleys.

METHODS

We surveyed Coahuila, Durango, Zacatecas, Chihuahua, and Sonora from October–December 1984. Golden Eagles were surveyed by car and on foot. Potential breeding areas were identified by using 1:50 000 topographic and vegetation maps. Because Golden Eagles are resident year-round, and because overwintering Golden Eagles could be also present in these areas, we made inquiries of local people familiar with Golden Eagles to better determine likely areas to search. These inquiries helped to more accurately determine potential nesting areas (Fuller and Mosher 1981). We were also guided by local people to some nesting areas. We spent at least 10 d in each state, except for Sonora, where we surveyed for 3 d. We did not determine the area of potential breeding habitat we visited because of the possibility some nests could have been overlooked and because there were not previous studies that showed the historical distribution of

Table 1. Sightings of Golden Eagles in northern states of Mexico 1984. Sightings in bold indicate individuals in potential and confirmed breeding areas.

LOCATION	STATE	NUMBER OF EAGLES	HABITAT	VEGETATION	ALTITUDE (m)	DATE
Rancho el Negro	Coahuila	**1[j]**	cliffs, canyons, extensive valleys	desert scrub	1480	12 October 1984
Sierra Maderas del Carmen	Coahuila	**1[a]**	cliffs in front extensive valleys	desert scrub	2000	12 October 1984
Universidad Autónoma Agraria Antonio Narro	Coahuila	**2[a], 1[j]**	canyons in sierras	rosetophyllous scrub with *Larrea*; highlandas with oak and oak-pine forest	1910	17 October 1984
Rancho Experimental Ganadero los Angeles	Coahuila	**1[?]**	small sierras and extensive grasslands, valleys	pine forest	1940	19 October 1984
Sierra el Campano, los Barrancos	Coahuila	**1[?]**	sierra, abundant cliffs, valley	desert scrub, dominated by mesquite *Prosopis* sp.	1880	18 November 1984
Sierra la Paila	Coahuila	**Common**	sierra, abundant cliffs	desert scrub	1200	18 October 1984
Navíos	Durango	**1[j]**	sierra	pine and oak-pine forest	2040	25 October 1984
Pueblo Nuevo	Durango	1[?]	sierra	pine and oak-pine forest	1000	26 October 1984
La Michilía	Durango	**1[j]**	sierra	pine, oak-pine forest, grasslands	2380	25 May 1979
		1[a]				2 March 1982
		1[a]				May 1983
		1[a]				14 August 1983
Rancho las Margaritas	Durango	**Common**	sierra	grasslands	2000	27 October 1984
Cerro San Ignacio, Mapimí	Durango	**2[a], 1**	isolated mountain, valley	xerophytic desert scrub, dominated by *Larrea, Agave, Opuntia, Fouquieria*	1300	11 February 1984
		1[a], 1[s]				
Coatillas o Hacienda Prediseño	Durango	1[a]	valley	xerophytic desert scrub	500	27 October 1984
Col. Guanjuato, Carretera a Fresnillo	Zacatecas	**3[?]**	sierra and valley	oak forest in sierra; desert scrub (*Opuntia, Larrea, Agave*) in valley	—	15 November 1984
Lobatos	Zacatecas	**1[?]**	sierra	oak forest	2000	16 November 1984
Adjuntas del Refugio, Sierra los Alamos	Zacatecas	**1**	sierra	oak-pine forest	1486	September 1984
Sierra de los Berros	Zacatecas	**1**	sierra, canyon	pine forest	1940	28 October 1984
Sierra de la Junta	Zacatecas	**1**	sierra	pine forest	1500	10 November 1984
Melchor Ocampo	Zacatecas	**1**	cliffs, sierra, extensive valleys	desert scrub, dominated by mesquite	1870	18 November 1984

Table 1. Continued.

Location	State	Number of Eagles	Habitat	Vegetation	Altitude (m)	Date
Tres Castillos, 9 km from Rancho las Tuzas	Chihuahua	2[a]	cliffs, valley, desert prairie	microphyllous scrub	1500	28 December 1984
Rancho las Palmitas, Sierra Gomeños	Chihuahua	3[a]	sierra, extensive valleys	*Larrea* and *Yucca* spp.	1560	28 December 1984
Nacori Chico, 24 km, south	Sonora	1[?]	cliff	pine forest	1180	November 1984
Cumpas (4 kms from the town)	Sonora	1[?]	sierra, valleys	microphyllous scrub	800	November 1984

[a] Adult.
[j] Juvenile.
[s] Subadult.
[?] Unknown.

Golden Eagles in Mexico. Moreover, we were interested in finding the greatest number of Golden Eagle nests to determine nesting habitat characteristics, but not the density of breeding pairs.

Golden Eagles were surveyed irregularly between 1984–96 in Baja California Sur. Surveys were made by car and on foot, using topographic maps (see Rodríguez-Estrella et al. 1991). Most of the records were obtained from the central part of Baja California peninsula, but individuals were also recorded in the southern part of the peninsula. We particularly surveyed the higher and the lower sierras, including isolated mountains. Vegetation of the area is desert thicket, comprised mainly of mesquite (*Prosopis* spp.), Adam's tree (*Fouquieria diguetti*), paloverde (*Cercidium microphyllum*), and columnar cacti cardons (*Pachycereus pringlei*) (see a detailed description in Rodríguez-Estrella et al. 1991). For northern Baja California, we also conducted a bibliographic survey of the available literature.

RESULTS AND DISCUSSION

Golden Eagles were common in the states of Coahuila (18 locations), Durango (17 locations), Chihuahua (16 locations), Zacatecas (13 locations), and Sonora (5 locations) (Fig. 1, Table 1). Interviews with local people showed that there were other areas where Golden Eagles were commonly observed, but we did not survey them. These areas included Sierra de la Paila, Ejido de Higueras, Ejido Casa Blanca, Sierra de Arteaga (Cañón El Colorado), Mesillas (El Paredón), sheep raising areas of Acuña, and La Muralla in Coahuila; Cofradías, Cebollas, Tepehuanes, Santiago Papasquiaro, Cambray, Ciénega de Escobar, and Rancho Santa Teresa in freeway Durango-Parral in Durango; Azafrán, Sierra de las Peñas in Cañón 2 Bocas, Pico de Teira, Manga del Sacramento, Tatalucas near Valparaíso, and Sierra Guadalupe de las Corrientes in Zacatecas; Sierra del Sueco, Colonia Benito Juárez, Cañón de Santa Clara, Sierra de la Esperanza, Ojo Laguna, Tepehuanes, Madera, Temosachic, Rancho Terrenatos, Sierra Catalina, Rancho El Escondido, Rancho Agua de Pérez, Rancho Maynas, and Mesa Tres Ríos in Chihuahua; San Pedro of Ejido Vicente Guerrero, and Cananea in Sonora. Most eagles were found in sierras with oak-pine forest vegetation and valleys with grasslands. However, Golden Eagles were also found to be common in xerophytic scrub vegetation.

We also recorded Golden Eagles in the Baja California peninsula (Fig. 2, Table 2). During April, July, and October 1984, November 1987, February–March 1988, October 1989, and January–May 1992, 1995, and 1996, we observed 27 adults, 1 subadult, and 5 immatures at different sites in Baja California Sur (Table 2, modified from Rodríguez-

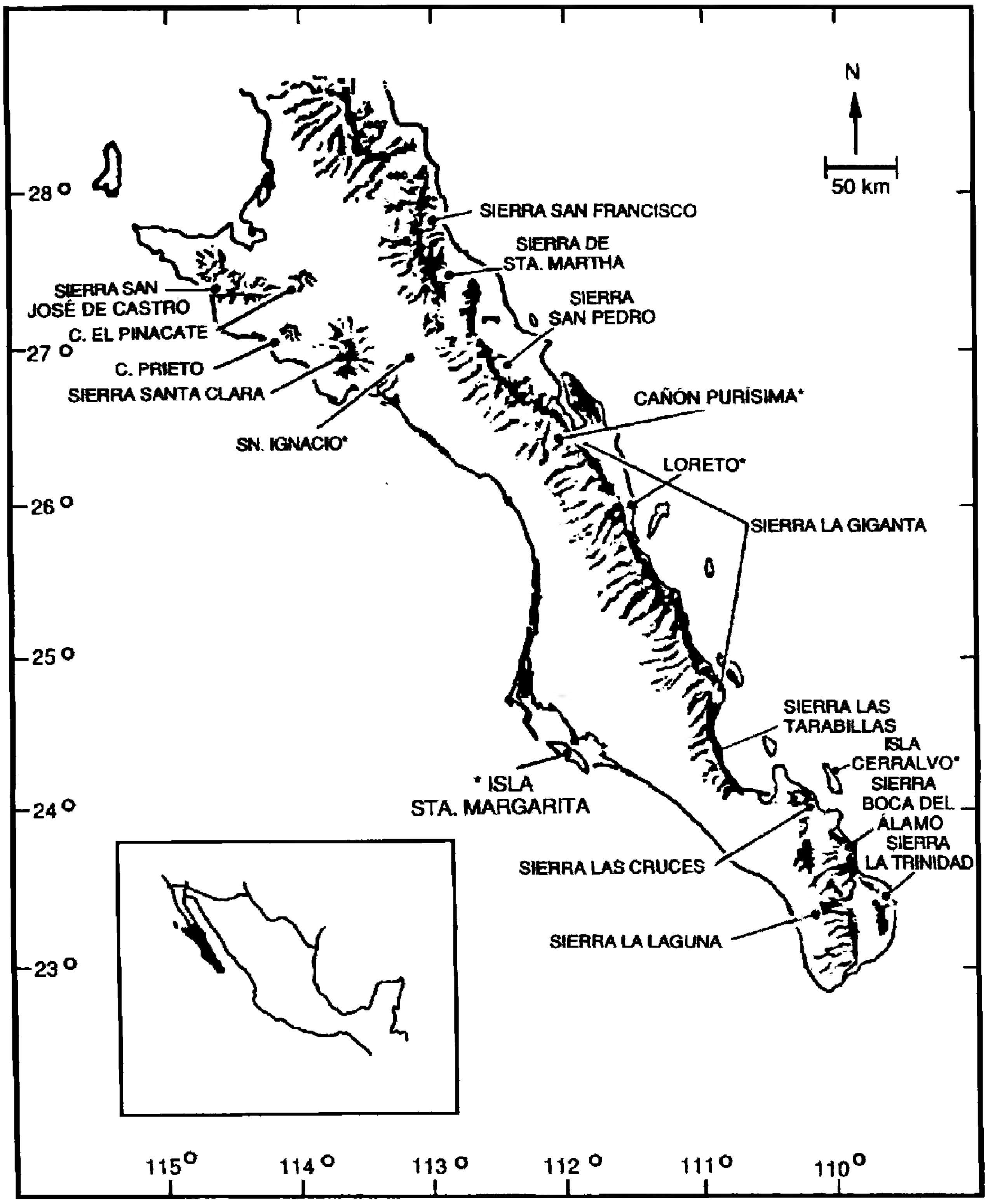

Figure 2. Baja California Golden Eagle records (from Rodríguez-Estrella et al. 1991).

Estrella et al. 1991). Oak-pine forest and xerophytic scrub vegetation were habitats where Golden Eagles were recorded in sierras and valleys. We found old nests that were apparently constructed by Golden Eagles, but recorded no breeding activity. Older local people recognize Golden Eagles and remember nests of the species in some areas, where they no longer nest.

CONCLUSIONS

The status of the Golden Eagle in Mexico is poorly known. Data on Golden Eagle breeding populations in northern Mexico are still scarce and not enough information exists to correctly determine population trends. Even at well-known sites, data collection has been irregular and little long-term breeding data (5–10 yr) exist. Ecological data are poor and knowledge of population trends does not exist. The information we present could help to determine a general trend in surveyed areas of northern and northcentral Mexico if a repeat survey is carried out. The status and distribution of Golden Eagles in Baja California has not been clearly determined (see Rodríguez-Estrella et al 1991). However, Golden Eagle population in Baja California Sur seems to be stable. Additionally, there could be two Golden Eagle populations in Baja California, one resident, nonmigratory breed-

Table 2. Historical Golden Eagle records from Baja California Peninsula (modified from Rodríguez-Estrella et al 1991). Numbers inside an entry indicate sightings of eagles. Each number indicates the number of individuals recorded in one site.

SITE	DATE	NUMBER OF INDIVIDUALS	SOURCE
North of Vizcaíno Desert			
Nachoguero (32°29′)	5 October 1946	1	Hill and Wiggins 1948
Ensenada (31°43′)	9 April 1967	1[a], 1[a]	Short 1967
Laguna Hanson (31°39′)	21 October 1926	1[b]	Grinnell 1928
	7, 8 October 1946	1, 2	Hill and Wiggins 1948
Santo Tomás (31°31′)	16 October 1946	Several	Hill and Wiggins 1948
San Telmo (30°49′)	1893	2[c]	Anthony 1893 (cited in Grinnell 1928)
	21 October 1946	3	Hill and Wiggins 1948
San José (30°48′)	October 1946	Nest[d]	Hill and Wiggins 1948
	20 October 1946	1	Hill and Wiggins 1948
San Quintín (30°31′)	25 February 1925	1	Huey 1926
La Grulla (30°04′)	15 June 1923	1	Huey 1926
San Fernando (29°59′)	1895	1	Anthony 1893 (cited in Grinnell 1928)
El Mármol (29°48′)	26 October 1946	1	Hill and Wiggins 1948
Isla San Lorenzo (28°31′)	17 April 1977	1	Wilbur 1987
Vizcaíno Desert			
Cerro El Pinacate (27°32′)	7, 9, 10–12 July 1984	1, 1, 1, 2, 2	Rodríguez-Estrella et al. 1991
Sierra San Francisco (27°31′)	11, 12 March 1988	1 , 1	Rodríguez-Estrella et al. 1991
	27 October 1989	2[a]	Rodríguez-Estrella et al. 1991
Sierra Santa Martha (27°25′)	19 March 1988	1	Rodríguez-Estrella et al. 1991
Sierra de la Cabra (27°24′)	17 November 1987	1	Rodríguez-Estrella et al. 1991
Sierra de Santa Clara (27°08′)	14 October 1984	2	Rodríguez-Estrella et al. 1991
	8 May 1996	2, 1	This study
San Ignacio (27°02′)	17 January 1985	1	Wilbur 1987
San Hipólito (26°59′)	13, 14, 17 April, 15 October 1984	1, 2, 2, 2	Rodríguez-Estrella et al. 1991
South of Vizcaíno Desert			
Cañón Purísima (26°20′)	17 November 1946	1	Hill and Wiggins 1948
Loreto (25°53′)	15 January 1985	1	Wilbur 1987
Isla Santa Margarita (24°24′)	25 April 1984	1	Amador 1985
Isla Cerralvo (24°12′)	26 October 1961	1	Banks 1963
Isla Espiritu Santo	May 1995	1	This study
Los Planes (24°05′)	June 1988	1	Rodríguez-Estrella et al. 1991
La Rivera (23°31′)	November 1989	1	Rodríguez-Estrella et al. 1991
Sierra de la Laguna (23°19′)	25 January 1990	1[a], 1	Rodríguez-Estrella et al. 1991
	3 February 2000	1	This study

[a] Immature.
[b] Skeleton in the Museum of Vertebrate Zoology, University of California, Berkeley, California U.S.A.
[c] Eagles nesting.
[d] A nest in good repair in a ponderosa pine (*Pinus ponderosa*).

ing population, and a migratory, overwintering population that breeds elsewhere, probably in the U.S. (Rodríguez-Estrella et al. 1991).

Golden Eagle numbers in Mexico have certainly decreased in some areas, especially in those areas heavily influenced by people. Many suitable habitats still exist in remote areas and Golden Eagles may persist in those habitats. Although local extinctions may be occurring in Mexico, the status on a regional scale is unclear.

More studies should be done to understand trends in Golden Eagle populations in northern and northcentral Mexico. The Golden Eagle National Recovery Plan (Plan Nacional de Recuperación del Aguila Real) encourages long-term studies of Golden Eagles in Mexico to better understand

the factors affecting populations on the local and regional scale. Current studies are now being done in Zacatecas, Durango, Chihuahua, and the Baja California peninsula. It is hoped that more information will be obtained in the coming years.

ACKNOWLEDGMENTS

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THE GOLDEN EAGLE IN NORTH CAUCASIA AND TRANSCAUCASIA

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Abstract.—In the 19th and early 20th centuries, the Golden Eagle (*Aquila chrysaetos*) was reported to be a widespread common species inhabiting highlands throughout Caucasia. At present, it is a rare resident in winter, but it is widely nomadic. Large mountain slopes along river valleys are preferred habitats. An essential requirement for hunting is the presence of open habitats. The upper limit of elevation of breeding individuals is 2400 m, but more typically they are found at <1900 m. The present population is estimated to consist of 220–225 pairs. In the Russian part of northern Caucasia, the population appears to be relatively stable, where by the end of 1990 at least 125 pairs bred along valleys of large rivers at Peredovoi and along the Main Caucasian Ridge and its spurs. Breeding pairs may occur along the Skalistyi Ridge, but it has not been confirmed. The Transcaucasian population is estimated at 75–95 breeding pairs distributed in mountain forests of the Main Caucasian Ridge, its southern spurs, and in the highlands of Lesser Caucasia. The numbers of breeding pairs in the Transcaucasian countries are estimated at 15–25 pairs in Armenia where it is more common in southern areas and possibly as many as 60 pairs in Azerbaijan where there were only 30–45 pairs in the 1980s. In Georgia, not more than 30 pairs occur in the mountain forests of Greater and Lesser Caucasia (Ajara-Imereti Ridge) and at least 60% of the population occurs in the eastern part of the country. Due to military conflicts, there are no recent data from Chechnya, Ingushetia, Dagestan, Karabakh, Abkhazia, South Ossetia, and adjacent areas. The population appears to have declined most seriously from 1940–70. Since then, there does not appear to have been any additional declines. Causes of the decline in the species include a sharp decline in food resources, mortality in traps set for mammalian predators, and disturbance in breeding territories. Due to this, Golden Eagles have been included in the Red Data Books of the ex-USSR, Armenia, Azerbaijan, Georgia, and Russia.

Key Words: *Golden Eagle*; Aquila chrysaetos; *Caucasia*; *distribution*; *conservation*.

El águila real en el norte del Cáucaso y Transcaucasia

Resúmen.—En el siglo XIX y principios del siglo XX, el águila real (*Aquila chrysaetos*) era reportada como una especie común y ampliamente distribuida que habitaba las tierras altas a lo largo y ancho del Cáucaso. En la actualidad es un residente raro pero, en invierno, es ampliamente nómada. Sus hábitats preferidos son las pendientes de las grandes montañas a lo largo de los valles de los ríos. Uno de sus requerimiento esenciales para cazar es la presencia de habitats abiertos. El limite altitudinal superior de individuos durante la reproducción es 2400 m, pero se encuentran mas típicamente a <1900 m. Se estima que la población presente consiste de 220–225 parejas. En la parte Rusa del Norte del Cáucaso, la población parece ser relativamente estable, allí al final de 1990 al menos 125 parejas procrearon a lo largo de los valles de los grandes ríos en Peredovoi y a lo largo de la principal cordillera Caucásica y sus estribaciones. Las parejas reproductivas pueden ocurrir a lo largo de la cordillera Skalistyi, pero esto no ha sido confirmado. La población transcaucásica se estima en 75–95 parejas reproductoras distribuidas en bosques de Montaña de la principal cordillera transcaucásica, sus estribaciones sureñas, y en las tierras altas del Cáucaso menor. Los números de parejas reproductoras en los países transcaucásicos se estiman en 15–25 parejas en Armenia en donde es mas común en áreas sureñas y posiblemente tantas como 60 parejas en Azerbaijan donde habían 30–45 parejas en los 1980s. En Georgia, no mas que 30 parejas ocurren en los bosques montañosos del Gran y Menor Cáucaso (Cordillera Ajara-Imereti) y al menos 60% de la población ocurre en la parte oriental del país. Debido a los conflictos armados, no hay datos recientes de Chechenia, Ingushetia, Dagestan, Karabakh, Abkhazia, Sur Ossetia, y areas adyacentes. La población parece haber declinado mas seriamente de 1940–1970. Desde entonces, parece que no ha habido declinaciones adicionales. Las causas del decline en la especie incluyen una abrupta disminución de los recursos alimenticios, muertes en trampas colocadas para

mamíferos predadores, y disturbios en los territorios de apareamiento. Debido a esto, las águilas reales han sido incluidas en los Libros de Datos Rojos de la ex-USSR, Armenia, Azerbaijan, Georgia, y Rusia.

[Traducción de César Márquez y Victor Vanegas]

Based on our long-term studies and observations, this report provides new information on population status, distribution, numbers, habitats, reproduction, and other biological aspects of the Golden Eagle (*Aquila chrysaetos*) in northern Caucasia and Transcaucasia. Until recently, the Golden Eagle has been one of the least studied species of the avifauna of Caucasia. A few short papers have been published on its status in some parts of the region; however, all have been based on casual observations. As a result, information has been scarce and contradictory. No previous long-term work on this species has been carried out within the region.

METHODS

Our research on Golden Eagles was done during the period 1973–99 in the Caucasian part of Russia and the Transcaucasian states of Georgia, Armenia, and Azerbaijan. Data on the distribution, numbers, and biology of the species were collected during field studies, from summaries and analyses of published data, and from unpublished reports. In all, 40 papers containing data on the species were examined. Most of the data were gathered during regular fieldwork in Georgia, western and central areas of Azerbaijan, northern Armenia, and some parts of northern Caucasia (Stavropol and Krasnodar regions, Dagestan).

Field methods are described in Abuladze (1990a). All known territories were checked every year. The diet was analyzed by means of direct observations and by analyzing pellets and remains of prey collected at and around nests. We identified prey remains using prey specimens previously collected in the study area and collections kept in the Institute of Zoology, Tbilisi, Georgia. Data on Golden Eagle numbers in some regions were gathered by local volunteers participating in counts carried out in the 1980s. Due to the unstable political situation and to financial problems, no fieldwork was carried out during the period 1992–94, but work was resumed in 1995.

RESULTS

Distribution and Numbers. The Golden Eagle is considered to be a rare, year-round resident with a restricted breeding range in the north Caucasian part of Russia and the Transcaucasian countries of Georgia, Armenia, and Azerbaijan. The number of Golden Eagles in the area decreased in the 20th century (Red Data Book of Georgian SSR 1982, Red Data Book of the RSFSR 1983, Red Data Book on Fauna of Armenian SSR 1987, Red Data Book of Azerbaijan SSR 1989). During the nesting season, it occurs only in upper forested belts of mountains and alpine meadows in the highlands of Greater and Lesser Caucasia. After the breeding season and in winter, the Golden Eagle is typically nomadic. Its change in behavior is related to its winter feeding habits as well as difficulties associated with hunting of live prey, marked seasonal declines in prey abundance, and unfavorable weather conditions in the highlands. In winter, it occurs in the lowlands, plains, tablelands, semideserts, and floodlands of large rivers, and as a vagrant in coastal wetlands along the Black and Caspian Sea coasts.

In northern Caucasia, breeding pairs of Golden Eagles occur on the slopes of the Skalistyi Ridge, Peredovoi Ridge, and the Main Caucasian Ridge and its spurs. In Georgia, breeding pairs are found on the slopes of the Main Caucasian Ridge and its spurs including Gagra, Bzipi, Chkhaltha, Kodori, Svaneti, Egrisi, Germukhi, Racha, Kharuli, Alevi, Mthiuleti, Gudamakari, Karthli, and Kakheti Ridges and Ajara-Imereti Ridge in Lesser Caucasia (Abuladze 1994, Kutubidze 1985, Zhordania 1992). In Azerbaijan, Golden Eagles occur on the southern macroslopes and spurs of the Main Caucasian Ridge and the Murovdag and Karabakh Ridges in Lesser Caucasia (Mustafaev and Gambarov 1977, Red Data Book of Azerbaijan SSR 1989, Patrikeev 1991, our data). Breeding pairs may occur along the border of Iran in Zuvand and possibly in parts of the Nakhichevan Autonomous Region, but there are no confirmed nesting records. In Armenia, Golden Eagles occur along the Zangezur, Bargushat, Bazum, Pambak, Vardeniz, Gegam, and Megri Ridges as well as Mount Aragats and the Karabakh Plateau (Red Data Book on Fauna of Armenian SSR 1987, Adamian and Klem 1997, our data).

Preferred breeding habitats of Golden Eagles include the watershed areas and upper belts of mountain slopes along valleys of large rivers that are separated by lateral valleys and covered by old forests. Topographically, these areas are very diverse and are typically adjacent to open areas such as large glades and pre-alpine and alpine meadows with rocky massifs and crossed by streams. Breeding sites are usually inaccessible to people. The elevational limits of the breeding distribution range from 700–3200 m, with nests occurring most often

at about 1900 m. Hunting territories are located in pre-alpine meadows along the upper limits of forests where there are high densities of Galliformes and other prey species.

We estimated the present total Caucasian population of Golden Eagles at 220–225 pairs (Abuladze 1997, Abuladze et al. 1998). There has been no change in the breeding distribution since the 1970s and the population appears to be stable. In northern Caucasia, the population is also stable and, at the end of 1990s, at least 125 pairs bred along the valleys of the large rivers in Greater Caucasia. Over 20 pairs occurred within the mountainous part of the Stavropol region (Khokhlov 1996), two nests were known in the North Ossetian Nature Reserve (Komarov 1985, Lipkovich 1988), and no less than 4 pairs occurred in the Caucasian Nature Reserve (Til'ba 1989, our data). Nesting pairs may also occur at the Skalistyi Ridge, but they have not been confirmed.

The Transcaucasian population is estimated at 75–95 breeding pairs, occurring in mountain forests of the Main Caucasian Ridge, its spurs, and the highlands of Lesser Caucasia. The Main Caucasian Ridge and its spurs support up to two-thirds of the breeding population. Within the Transcaucasian countries, there are perhaps 15–25 pairs currently in the southern portion of Armenia. In Azerbaijan, the total number has been estimated at 13–16 pairs (Red Data Book of Azerbaijan SSR 1989), but our data do not agree with this estimate. Our data, collected in the 1980s, indicated that no less than 15 nesting territories occurred in the northern and western parts of the country. Based on this and data information from local specialists and amateurs, we estimate the number of pairs in the Azerbaijan part of Greater Caucasia is 30–35 breeding pairs and, in Lesser Caucasia, it is 10–20 breeding pairs. The possibility of several breeding pairs in mountainous areas along the border with Iran cannot be ruled out, but there is no information available. Therefore, we concluded that as many as 60 pairs of Golden Eagles breed in Azerbaijan.

The Georgian population is estimated at not more than 30 breeding pairs, which occur in the mountain forests of the Main Caucasian Ridge, its spurs, and Lesser Caucasia. On the southern macroslopes of Greater Caucasia in eastern Georgia, we estimated that there are about 20 pairs and no significant changes have occurred in the status of the population in this area from 1970–90. Numbers of breeding pairs were stable varying between 27–30 pairs. Based on our results, we concluded that there has been an increase in the population in recent years on the macroslopes of Greater Caucasia, within the watershed area of the Ajara-Imereti Ridge, and along the Turkish border. This may be attributed to the sharp decline in human activity (e.g., forest destruction, heavy grazing, construction of roads, and recreational pressure) in the 1990s. It is possible that the total number of breeding pairs is gradually increasing and, at present, it could be as high as 35–40 breeding pairs.

The Golden Eagle population in the region of northern Caucasia and Transcaucasia has remained relatively stable during last two to three decades. There are no recent data from Abkhazia, Karabakh, Chechnya, Dagestan, Ingushetia, and South Ossetia due to military conflicts in these areas.

Breeding Biology. Golden Eagles are resident and territorial throughout the area and nesting areas are used for many years in succession. Each pair has as many as 4 nests, usually situated within a relatively restricted area. Nests are used in turn, sometimes with intervals of several years between occupations. Pairs appear at nesting sites from late February to early March. We recorded 54 courtship display flights from 26 February–19 March. Repair of old nests and building of new ones also occurs at this time. Nests are constructed on extremely inaccessible cliffs often in the upper parts of vertical rocks, cliffs in gorges, rocky ridges, walls of canyons in the forest belt of mountains, and at the upper limits of forests. Nests are built on shelves under ledges, small caves and niches, and in cracks. In the foothill regions of the Stavropol area, nests are usually built on rock outcrops, using juniper (*Juniperus* spp.) shrubs to support the base. We did not record nests in trees, and there is no mention of tree-nesting in the region. All nests occurred between 920–2400 m and most (31 of 39 nests) were located between 1400–1800 m. The direction of exposure was usually toward the southeast or east (southeast = 19, east = 9, southwest = 4, south = 2, south southwest = 1, west = 1, northwest = 1, north northeast = 1 nest). Nests measured 1.0–1.3 m in diameter and 0.3–0.5 m in height. Typically, they consisted of dry branches of various lengths and 5–20 mm in thickness. The nest cup was lined with dry grass and sheep wool. Occupied nests are decorated with fresh twigs from conifer trees.

Eagles hunt at distances of 0.3–2.0 km from their nest sites. All known nest sites were located at lower

Table 1. Measurements of Golden Eagle eggs in Georgia.

CLUTCH	LENGTH (mm)	WIDTH (mm)	MASS (gm)	DATE	LOCATION OF NEST (ELEVATION m)
1	72.5	56.3	—	24 March 1978	Lagodekhi Reserve, Matzimi Gorge (1840 m)
	71.5	56.0	—		
2	74.3	57.5	124.0	2 April 1982	Terek River valley, Darial Gorge (1480 m)
	73.0	56.5	120.1		
3	76.2	58.0	—	19 April 1984	Abkhazia, Bzipi Ridge (1765 m)
4	73.2	57.7	123.5	10 April 1988	Dusheti district, Lomisi Ridge (1910 m)
	72.0	55.8	121.2		
5	75.5	57.0	120.8	7 April 1990	Kazbegi district, vicinity of Sno (1870 m)
6	74.0	57.5	124.6	11 April 1991	Borjomi Nature Reserve
	71.7	55.5	121.0		Kvabiskhevi Gorge
Min	71.5	55.5	120.1		
Max	76.2	58.0	124.6		
$\bar{x}$	73.4	56.8	122.2		

altitudes than hunting areas. This probably allowed the birds easier transportation of prey to nests in these mountainous areas.

Copulation was recorded on 28 February and 3 and 7 March. Eggs were laid in the latter half of March (19 March–3 April), mainly in the last 10 d of March. Normally, full clutches have either one or two eggs. Among 41 monitored clutches, 6 (14.6%) contained one egg and 35 (85.4%) contained two eggs. In total, 41 clutches consisted of 76 eggs with an average clutch size of 1.85 eggs. The average size of 10 measured eggs in six clutches was 73.39 × 56.78 mm (range = 71.5–76.2 mm × 55.5–58.0 mm). The average weight of seven eggs in four clutches was 122.17 g (range = 120.1–124.6 g) (Table 1). Incubation lasted 44–45 d.

Hatching occurred in the first two weeks of May with young hatching from 5–16 May (N = 9). Young left nests in late July or early August (range = 27 July–7 August, N = 10). In all successful nests, only one young survived to fledging (N = 43).

Data on 78 nesting attempts were obtained in 1978, 1981, and 1985–91 (Table 2). In addition to our own data on 41 breeding attempts, we also obtained unpublished data collected in different parts of Caucasia. Our own data were collected mostly in western and central parts of the southern macroslopes of Greater Caucasia, the territory of Georgia, and northwestern Azerbaijan. The total number of breeding territories observed each breeding season ranged from 4 in 1976 to 12 in 1985. An average of 77.4% (range = 60.0–90.9%) of these nesting attempts was successful fledging an average of 0.79 fledglings per successful attempt (range = 0.7–1.0 fledgling). The mean number of fledglings per occupied territory was 0.61 (range = 0.44–0.83) and the mean number of fledglings per nesting pair was 0.68 (range = 0.5–0.83).

Data were collected in Georgia in 1995–97. In eastern Georgia, at least 5 breeding pairs raised 4 young in 1995 and 4 breeding pairs in the Aragvi and Terek River basins and Ajaria raised 2 and 3 young in 1996 and 1997, respectively. No differences in nesting success were evident from 1970–98. Breeding pairs were very aggressive to nomadic, nonbreeding eagles that were near occupied nests.

Feeding Ecology. The diet was studied in detail in Greater Caucasia in Georgia and northwestern Azerbaijan. The diet of the Georgian population was similar to that recorded in other parts of Caucasia. Nevertheless, there were some regional differences that reflected the local availability of certain prey species. Altogether 189 prey items were identified (Table 3). Of these, 88 (46.6%) were mammals (12 species) and 101 (53.4%) were birds (17 species). Dominant prey species were the European hare (*Lepus europaeus,* 12.7%) and Galliformes, especially Caucasian Snowcocks (*Tetraogallus caucasicus,* 16.4%), Caucasian Black Grouse (*Tetrao mlokosiewiczi,* 12.7%), and Chukars (*Alectoris chukar,* 8.5%). Marked variation in diet occurred between years and locations. The main causes for variation in diet were annual variation in the numbers of

Table 2. Breeding success of Golden Eagles in Caucasia.

	YEARS								
INDICES[1]	1978	1981	1985	1986	1987	1988	1989	1990	1991
A	7	10	12	10	9	10	6	7	7
B	5	10	11	10	9	8	6	6	7
C	5	9	11	9	8	7	5	6	5
D	4	8	10	7	5	6	3	5	4
E	1	1	1	2	3	1	2	1	1
F	80.0	88.9	90.9	77.8	62.5	85.7	60.0	83.3	80.0
G	4	6	7	5	4	5	3	5	4
H	1.0	0.75	0.7	0.71	0.8	0.83	1.0	1.0	1.0
I	0.8	0.6	0.64	0.5	0.44	0.63	0.5	0.83	0.57
J	0.8	60.67	0.64	0.56	0.5	0.71	0.6	0.83	0.8
K	2	0	1	0	0	2	0	1	0

[1] A—Number territories checked, B—Number territories occupied with pairs, C—Number territories with eggs, D—Number successful nesting attempts, E—Number unsuccessful nesting attempts, F—Percent of successful nesting attempts (D/C), G—Number of fledglings, H—Number of fledglings/successful nesting attempt (G/D), I—Number of fledglings/occupied territory (G/B), J—Number fledglings/established nesting attempt (G/C), K—Number territories with no activity.

prey, especially rodents; seasonal variation in availability of prey influenced by factors such as timing of hibernation, timing of reproductive period, emergence of young rodents from burrows, and the fledgling and migratory behavior of birds; daily variation in prey availability caused by activity patterns of the prey species; influences of habitat on species composition, numbers, and availability; influences of weather conditions on prey availability; and differences between individual eagles or pairs.

In addition to live prey, Golden Eagles also fed on carrion, especially in winter, including the remains of items killed by wolves (*Canis lupus*) (Abuladze and Baratashvili 1982). In all, 157 cases of carrion feeding were recorded (Table 4). We made 22 observations of eagles feeding to satiation on carrion on the western slope of Mount Didi Borbalo on 6 June 1978 and the eastern slope of Mount Diklo on 28 July 1980. Mean feeding time was 41.35 min (range = 18–66 min). Eight cases of kleptoparasitism were recorded on other eagles, and twice on Common Buzzards (*Buteo buteo*).

DISCUSSION

Threats and Limiting Factors. The greatest decline in the Golden Eagle population in the region occurred from 1940–70. Increasing human disturbance, including the construction of public and forestry roads in the highlands, the felling of native mountain forests, recreational pressure, and use of insecticides in forestry all contributed to the decline. In addition, the main problem was an organized campaign to exterminate birds of prey in the former USSR, including Caucasia, before the mid-1970s (Abuladze 1986). Other factors contributing to the decline were a sharp decline in available food, mortality in traps and from poisoned baits, and various forms of human disturbance in breeding habitats. From 1960–90, one of the major threats to the population was human disturbance from recreational pressure caused by tourists and alpinists. During this time, Caucasia was one of the most popular tourist areas in the former USSR. After 1991 and following the breakup of the USSR, this form of human disturbance has practically disappeared.

At present, main threats to the population are illegal shooting, mortality in traps, and poisoned baits. Human disturbance has been largely absent from some areas in recent years. In addition, some new dangers now threaten the species. Prior to the 1990s, extensive sheep breeding was the most common form of stock raising in Caucasia. Numerous flocks of sheep annually moved from winter pastures in steppe areas in the lowlands of Lesser Caucasia to summer pastures in the alpine meadows of Greater Caucasia. Numbering in the millions, these sheep were one of the main sources of food for large raptors, including Golden Eagles. At that time, there were no state borders between the various Caucasian republics and the administrative borders were crossed by shepherds who drove sheep to pastures on the lowest passes of the Main

Table 3. Prey recorded from pellets and food remains of Golden Eagles collected in Georgia, 1977–99.

PREY SPECIES	NUMBER	% FREQUENCY
Mammals		
Hedgehog (*Erinaceus europaeus*)	1	0.5
Shrews (*Sorex* spp.)	3	1.6
European hare (*Lepus europaeus*)	23	12.2
Red squirrel (*Sciurus vulgaris*)	9	4.8
Caucasian squirrel (*Sciurus anomalus*)	1	0.5
Fat dormouse (*Glis glis*)	2	1.1
Wood mouse (*Apodemus sylvaticus*)	7	3.7
Mice (*Mus* spp.)	14	7.4
Voles (*Microtus* spp.)	12	6.3
Rodents (*Rodentia* spp.)	11	5.8
Chamois (young) (*Rupicapra rupicapra*)	1	0.5
Domestic goat (young) (*Capra hircus*)	1	0.5
Common marten (*Martes martes*)	1	0.5
Stone marten (*Martes foina*)	2	1.1
Total mammals	88	46.6
Birds		
Mallard (*Anas platyrhynchos*)	1	0.5
Caucasian Snowcock (*Tetraogallus caucasicus*)	31	16.4
Caucasian Black Grouse (*Tetrao mlokosiewiczi*)	24	12.7
Chukar (*Alectoris chukar*)	16	8.5
Quail (*Coturnix coturnix*)	2	1.1
Domestic hen (*Gallus domesticus*)	2	1.1
Woodcock (*Scolopax rusticola*)	2	1.1
Common Wood Pigeon (*Columba palumbus*)	2	1.1
Tawny Owl (*Strix aluco*)	1	0.5
Black Woodpecker (*Dryocopus martius*)	1	0.5
Great Spotted Woodpecker (*Dendrocopos major*)	1	0.5
Song Thrush (*Turdus philomelos*)	1	0.5
Ring Ouzel (*Turdus torquatus*)	3	1.6
Thrushes	2	1.8
Eurasian Jay (*Garrulus glandarius*)	1	0.5
Hooded Crow (*Corvus corone cornix*)	1	0.5
Yellow-billed Chough (*Pyrrhocorax graculus*)	5	2.6
Corvids	3	1.6
Small Passeriformes	2	1.1
Total birds	101	53.4
Total number of prey	189	100

Caucasian Ridge. Since 1992, free movement across these borders has become very difficult, and in many places impossible. Border constraints, new forms of human activity prompted by land privatization, and a developing economic crisis together with the general social unrest and military events which have occurred during the last decade have contributed to the end of traditional forms of pastoralism and livestock rearing. In the last decade, sheep numbers have dropped dramatically leading to a reduction in the food resources for large raptors.

In total, 38 cases of mortality of eagles were recorded during the study period. The main cause was illegal shooting. Unfortunately, in spite of legal protection in the Caucasian states, 14 cases of shooting (36.8%) were noted in 1973–96. An additional 14 eagles (36.8%) were caught in baited traps set for predatory mammals such as wolves, foxes, and jackals. Poisoned baits also create a serious danger. A total of 8 eagle mortalities (21.1%) were recorded. The distribution of all known causes of death of adult eagles in Caucasia by season was as follows: 21 (55.3%) in winter, 10 (26.3%)

Table 4. Species taken as carrion by Golden Eagles in Caucasia.

CARRION SPECIES	NUMBER	% FREQUENCY
Domestic sheep (*Ovis* dom.)	77	49.0
Goat (*Capra hircus*)	11	7.0
Cattle	15	9.5
Domestic pig (*Sus scrofa* dom.)	7	4.5
Horse (*Equus caballus*)	6	3.8
Donkey (*E. asinus domesticus*)	2	1.3
Domestic dog (*Canis familiaris*)	4	2.3
Total domestic mammals	122	77.7
Caucasian red deer (*Cervus elaphus*)	10	6.4
West Caucasian goat (*C. caucasica*)	2	1.3
East Caucasian goat (*C. cylindricornis*)	18	11.5
Chamois (*Rupicapra rupicapra*)	1	0.6
European wild boar (*Sus scrofa*)	2	1.3
Roe deer (*Capreolus capreolus*)	1	0.6
Common fox (*Vulpes vulpes*)	1	0.6
Total wild mammals	35	22.3
Overall total	157	100

during the breeding season, and 7 (18.4%) in the postbreeding period and in autumn.

Egg loss mostly resulted in the loss of entire clutches. Hatching failure was due to the protracted interruption in incubation during early stages of incubation. This was probably the result of disturbance at nests by people. In two cases, corvids robbed clutches and one nest was robbed by a person.

Conservation. Golden Eagles are included in the Red Data Books of ex-USSR (1984), Russia (1983), Georgia (1982), Armenia (1987), and Azerbaijan (1989). The birds, their nests, and breeding and feeding habitats are protected in the following nature and game reserves: Caucasian Nature Reserve (263 300 ha), Teberda Nature Reserve (85 000 ha), Kabarda-Balkarian Nature Reserve (74 100 ha), North Ossetian Nature Reserve (30 000 ha), and Guton Game Reserve (34 600 ha) in Russia; Shikakhokh Nature Reserve (10 000 ha), Khosrov Nature Reserve (29 200 ha), and Dilijan Nature Reserve (28 000 ha) in Armenia; Pirkuli Nature Reserve (1520 ha), Zakatala Nature Reserve (23 800 ha), Gei-Gel' Nature Reserve (6739 ha), Ilisu Nature Reserve (9300 ha), and Ismaily Nature Reserve (5800 ha) in Azerbaijan; and Ritza Nature Reserve (16 300 ha), Pskhu-Gumista Nature Reserve (40 800 ha), Borjomi Nature Reserve (18 000 ha), Kazbegi Nature Reserve (8700 ha), Akhmeta Nature Reserve (16 300 ha), Lagodekhi Nature Reserve (17 800 ha), Kintrishi Nature Reserve (13 893 ha), and Kabali Game Reserve (6500 ha) in Georgia. All known nests are located on state-owned land (Sokolov and Syroechkovskii 1990, Abuladze 1990b).

The main measures needed for effective conservation of the Golden Eagle in Caucasia include more extensive surveys covering all parts of the region to obtain more accurate information on the population size, registration of all known nests and granting them special protection, strict control of the use of traps for predatory mammals in the breeding and feeding habitats of Golden Eagles, a ban on poisoned baits throughout all Caucasia, strict control of illegal hunting, extension of some nature reserves, provision of additional carrion in winter, intensive use of the mass media to enlist public interest and support, cooperation and joint efforts between all Caucasian specialists in order to coordinate the study and conservation of the species in this region, and establishment of a working group for the study and protection of the Golden Eagle in Caucasia.

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THE STATUS OF THE GOLDEN EAGLE (*AQUILA CHRYSAETOS*) IN HUNGARY

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ABSTRACT.—This paper describes the colonization of Hungary by Golden Eagles (*Aquila chrysaetos*) and the increase of the population from 1 pair in 1985 to 4 pairs in 1999. It documents the breeding performance each year (1985–99) and lists food items collected at nests during this period.

KEY WORDS: *Golden Eagle*; Aquila chrysaetos; *Zemplén Mountains*; *Hungary*; *colonization.*

El estado de el águila real (*Aquila chrysaetos*) en Hungría

RESÚMEN.—Este articulo describe la colonización de Hungría por las águilas reales (*Aquila chrysaetos*) y el incremento de la población desde la 1 pareja en 1985 a 4 parejas en 1999. Documenta el desempeño reproductivo cada año (1985–99) y lista los ítems alimenticios colectados en los nidos durante este periodo.

[Traducción de César Márquez y Victor Vanegas]

Although the Golden Eagle (*Aquila chrysaetos*) has been recorded from time to time in Hungary, it was not documented as a nesting species until the mid-1980s. Herein, I report the results of surveys conducted in the Zemplén Mountains of northeastern Hungary that document the current breeding population of four pairs.

STUDY AREA AND METHODS

The Zemplén Mountains are situated in northeastern Hungary and they belong to the Inner Carpathian system which is of volcanic origin. They extend 55–60 km from north to south and 15–20 km from east to west occupying an area of about 1430 km^2. Elevations range from 400–500 m and the principal vegetation types consist of Carpathian beech forests (*Deschampsio-Fagetum*), oak forests on nonlime soils (*Genisto tinctoriae-Quercetum petraeae*), and hornbeam-oak forests (*Carpinetum* spp.-*Querceto petraeae*).

I searched the mountains thoroughly for evidence of Golden Eagle breeding. Once a pair of eagles was located, the area was searched systematically to find each nest. Breeding behavior was monitored from February when nesting first began. Observations were made with great care to avoid disturbing the eagles. Where nests were accessible, the young were banded and food remains were collected from around each nest.

RESULTS

During the early 1980s, immature Golden Eagles were observed each year in the Zemplén study area. Several nests were built, but breeding did not occur. In 1985, a pair occupied a breeding territory and built and rebuilt a nest, but no young were raised. In 1987, two pairs of eagles were located. One pair did not breed but the other pair successfully raised one young (Table 1). In 1993, two new pairs of eagles were found. One pair nested in what was traditionally a productive Imperial Eagle (*A. heliaca*) nest, taking over the territory from an Imperial Eagle that had been unmated for some time. The Golden Eagle pair bred and successfully fledged young from this nest. The second new pair of eagles that was found did not build a nest in 1993. I constructed an artificial nest in a location in the territory where the eagles were seen perching during the day and roosting at night and the pair subsequently used this nest. In 1994, a pair of Golden Eagles again occupied the Imperial Eagle territory. In earlier years, the two species had coexisted and successfully bred within 1 km of each other. The pair of eagles occupied the artificial nest again in 1994. This time, they raised one young which died from unknown causes when it was about 8 wk of age. Currently, all four pairs of Golden Eagles continue to occupy breeding territories in the Zemplén study area and several other unpaired eagles have been observed in surrounding areas.

Golden Eagles in Hungary have a relatively catholic diet, feeding on a wide range of birds and mammals (Table 2).

CONSERVATION

Information on breeding performance of the pairs of Golden Eagles in Hungary is given to au-

Table 1. Breeding history of Golden Eagles in Hungary since 1985.

YEAR	NUMBER OF NESTING PAIRS	NUMBER OF NESTLINGS	NUMBER OF FLEDGLINGS
1985	1	0	0
1986	1	0	0
1987	1	0	0
1988	2	1	1
1989	2	1	1
1990	2	2	1
1991	2	0	0
1992	2	2	2
1993	2	0	0
1994	2	0	0
1995	4	3	2
1996	4	2	2
1997	4	5	4
1998	4	2	2
1999	4	2	2
Total	4	20	17

thorities responsible for the conservation and protection of nature in the region. These records help to keep protection policy up to date and to guide any restrictions on agricultural and forestry activity in the region. Relationships with foresters in the region are good and on several occasions they have provided observations on Golden Eagles.

Table 2. Prey species recorded at nest sites of Golden Eagles in Hungary.

PREY SPECIES	NUMBER OF ITEMS
Fox (*Vulpes vulpes*)	9
Rabbit (*Oryctolagus cuniculus*)	7
Deer (*Odocoileus* spp.)	4
Pine martin (*Martes martes*)	3
Mouflon (*Ovis musimon*)	1
Badger (*Meles meles*)	1
Cat (*Felis domesticus*)	1
Wild boar (*Sus scrofa*)	1
Common vole (*Microtus arvalis*)	1
Ring-necked Pheasant (*Phasianus colchicus*)	11
Ural Owl (*Strix uralensis*)	4
Unidentified birds	2
Woodpecker (*Picidae*)	1
Pigeon (*Columba livia*)	1
Chicken (*Gallus gallus*)	1
Magpie (*Pica pica*)	1

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I wish to thank all of those who with their frequent observations have contributed to the preservation of this species over the past years. Also, I would like to thank them for their useful observations that have helped extend our knowledge of the species in Hungary. In particular, I thank I. Béres, L. Losonczi, Z. Petrovics, and Z. Szegedi. Special thanks are due to J. Balogh who gave advice on the manuscript, and to B. Solti who analyzed the food remains.

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CONSERVATION OF THE GOLDEN EAGLE (*AQUILA CHRYSAETOS*) IN THE EUROPEAN ALPS—A COMBINATION OF EDUCATION, COOPERATION, AND MODERN TECHNIQUES

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Abstract.—At the beginning of the 20th century, the Golden Eagle (*Aquila chrysaetos*) was close to extinction in many parts of the European Alps. At the end of the century, the population has stabilized at around 1100 breeding pairs. To maintain the population, management strategies have been derived from models of habitat quality and distribution within the eagle's entire alpine range. These models were validated using a variety of data sources. They indicate that there are significant "hot spots" in distribution in the European Alps. Conclusions concerning the habitat quality of particular areas were derived by combining the models with data on human influences on alpine ecosystems, using a Geographic Information System (GIS). Scenarios to estimate the potential impact of future human activities on the breeding success and distribution patterns of the Golden Eagle were calculated from these models. The importance of the Golden Eagle as an environmental indicator for areas of open land in the Alps is considered for future conservation activities. The most effective way to ensure a viable population of Golden Eagles in the European Alps will be to enlist the close cooperation of conservationists and land users, as well as intensive environmental education and user-specific public relation activities.

Key Words: *Golden Eagle*; Aquila chrysaetos; *conservation*; *management*; *European Alps*; *habitat quality models*; *environmental education.*

Conservacion del águila real (*Aquila chrysaetos*) en los Alpes Europeos—una combinacion de educacion, cooperacion, y tecnicas modernas

Resúmen.—A principios del siglo 20, el águila real (*Aquila chrysaetos*) estuvo cerca de la extinción en muchas partes de los Alpes Europeos. Al final del siglo, la población se ha estabilizado alrededor de 1100 parejas reproductivas. Para mantener la población, las estrategias de manejo han derivado de modelos de calidad de hábitat y distribución dentro de todo el rango alpino del águila. Estos modelos fueron validados usando una variedad de fuentes de datos. Ellos indican que hay unos "puntos calientes" significativos en distribución en los Alpes Europeos. Las conclusiones concernientes a la calidad de hábitat de áreas particulares fueron derivadas combinando los modelos con datos sobre la influencia humana en los ecosistemas alpinos, usando un Sistema de Información Geográfica (SIG). Los escenarios para estimar el impacto potencial de futuras actividades humanas en el éxito reproductivo y los patrones de distribución del águila real fueron calculados a partir de estos modelos. La importancia del águila real como un indicador ambiental para áreas abiertas en los Alpes es considerada para futuras actividades en conservación. La mas efectiva manera de asegurar una población viable de águilas reales en los Alpes Europeos será enlistar la estrecha cooperación de los conservacionistas y los usuarios de las tierras, al igual que una educación ambiental intensiva y actividades de relaciones publicas usuario-especificas.

[Traducción de César Márquez y Victor Vanegas]

After a severe decline at the end of the 19th and the beginning of the 20th centuries, the Golden Eagle (*Aquila chrysaetos*) population in the European Alps is now estimated at about 1100 breeding pairs (Brendel 1998) and almost all suitable habitats appear to be occupied (Brendel et al. 2000). The population appears to be regulated through intraspecific competition in many parts of its alpine range (Jenny 1992). However, human-related changes in hunting areas used by Golden Eagles, especially in open land areas and alpine pastures above and below timberline, and disturbances within 300 m of nesting sites could alter the current status of the Golden Eagle population (Brendel et al. 2000).

Almost 500 million tourists visit the European Alps each year (Siegrist 1998) and this number is increasing, as is activity of helicopters and paragliders. Therefore, long-term conservation and management measures must be developed to avoid future declines in the eagle population caused by changes in its hunting habitats and disturbances at its nest sites (Brendel and d'Oleire-Oltmanns 1996). An environmental education program, involving close cooperation with user groups such as paragliders, has shown to be the most successful way to establish local conservation strategies and change human behavior. This could also provide a better understanding of eagles and their ecological needs in order to improve the acceptance of management recommendations (Brendel et al. 2000).

STUDY AREA

The geomorphological structure of the Alps is very heterogeneous, making it difficult to study the habitat preferences and population density of Golden Eagles in the area. For this reason, it was necessary to choose a study area with excellent digital data in order to develop general models on habitat preference and density which can then be validated by using long-term observational data and finally extrapolated to larger areas. The Berchtesgaden National Park (210 km^2) is located in the southeastern part of Germany within the Berchtesgaden Biosphere Reserve (460 km^2), close to the border of Austria. It represents a comparatively small part of the "northern limestone Alps" as well as the northern limit of the distribution of Golden Eagles within the European Alps (total area 200 000 km^2).

METHODS

Geographic Information System. Habitats of animals and their relationships toward each other have been investigated in the Berchtesgaden National Park for over 15 yr using a Geographic Information System (GIS). The GIS utilizes more than 150 landcover types derived from interpretation of color infrared (CIR) photos, and provides a detailed digital database of habitats within the study area. In addition, the GIS incorporates a digital elevation model based upon 20 m increments between 500–2750 m.

Modeling. Models concerning habitat quality and potential settlement density were derived from published ecological data on Golden Eagles (Glutz v. Blotzheim 1971, Jenny 1992, Bezzel 1976, Bezzel and Fünfstück 1994, Zechner 1995, Haller 1996, Watson 1997) to identify the most important habitats and actual areas of concentration or distributional "hot spots." Data were interpreted using ARC/INFO (Eberhardt 1996) for the area of the Berchtesgaden Biosphere Reserve (BR).

To predict habitat preferences of eagles in the study area, the most important factors were aggregated within three parameter classes: flight conditions (thermal + slope updrafts), prey abundance (active prey + carrion), and permanent human disturbances (e.g., roads, trails, and cable railways). These parameters were evaluated and then integrated into the final model (Eberhardt 1996). To provide evidence of spatial preferences, it was necessary to consider localized relationships between areas of different suitability classes (e.g., if a small area with high habitat quality is surrounded by many others of low habitat quality, that particular area will probably be avoided because of high energetic costs for the species). We used the "Kernel-HSI-Procedure" (Eberhardt et al. 1997, Eberhardt in press) to generate a "habitat suitability index" for Golden Eagles (Eberhardt et al. 1997). In addition, habitat quality during winter was assessed using a modified model that considered only the period when snow cover occurred (Eberhardt 1996). Home range sizes were determined from direct visual and telemetry observations of eagles by using the Kernel-Estimator (Worton 1989, Naef-Daenzer 1993, Bögel and Eberhardt 1997).

To explain different settlement densities and to identify areas of Golden Eagle concentration within the Alps, the parameter "landscape compartments" which can be derived from ground relief (Brendel et al. 2000) was used, as recommended by Haller (1996).

Model Transformation. The digital database for the European Alps proved to be very heterogeneous with a large amount of variation in quality between different countries and even within regions. For example, the "Arealstatistik" for Switzerland provides information on 73 landcover types derived from 100 × 100 m orthophotos, while the CORINE-classification for Germany, France, Italy, and Austria delineates 44 landcover types derived from 1:100 000 satellite photos. Therefore, for the step-by-step transformation of the detailed models for the Berchtesgaden BR to larger areas and finally to the whole Alps, some important simplifications had to be implemented. For example, landcover types were aggregated into 13 classes considered to be relevant to eagles. Also, we had to increase the scale from 1:25 000 to at least 1:1 000 000 for the whole European Alps because of the lack of comparable, detailed digital elevation models and heterogeneous landcover types across regions. To validate the predictions in these large-scale models concerning habitat quality and distribution, it was necessary to select different test areas within the Alps, which combined high quality observational data as well as digital data (Brendel et al. 2000).

Validation of the Models. A monitoring program, long-term database on Golden Eagles, telemetry data, and detailed knowledge of local experts provided the validation of the models we developed for the study area (Brendel et al. 2000). The predictions for other test areas were validated by comparing the models with local and regional data concerning Golden Eagle distribution and habitat quality. This was done for Kanton Graubünden, Switzerland (Brendel et al. 1998), all of Switzerland, South Tyrol, Italy, Vanoise National Park, France, and the Bavarian Alps, Germany.

Applications in Nature Conservation. The results of the Golden Eagle project at the Berchtesgaden National Park were transformed into management recommendations. One of the most important targets was to promote the acceptance of recommendations in local areas to conserve Golden Eagles. To achieve this, we devel-

oped an extensive environmental education program and close links with user groups like the German Bundeswehr (army helicopters), local paragliders, and climbers. The environmental education program consisted of presentations, public relations efforts, guided tours, and an exhibition as well as "experience trails." These trails lead National Park visitors to places where they have an opportunity to observe Golden Eagles with telescopes at perching and roosting sites and winter feeding areas without disturbing them. The aim was to let people take part in the fascination of eagles and learn about ecological connections within the alpine ecosystem.

Helicopter and paraglider pilots were trained in eagle conservation and were taught how to recognize when eagles are being disturbed and, most importantly, how to avoid disturbing nesting eagles. Blackboards were installed permanently at the launch sites of paragliders informing them about sensitive areas such as breeding cliffs. The boards also showed suggested alternate flight routes that lead them to areas with excellent thermal updrafts, but with a low potential for disturbing eagles.

RESULTS

Modeling and Validation. The literature-based habitat-suitability-models (HSM) for the Golden Eagle that incorporated prey availability, slope/thermal updrafts, and human disturbance in the study area were broadly consistent with radiotelemetry data on the behavior of one territorial female and long-term observation data for 13 eagle pairs in the study area. The essential habitat elements were similar in both summer and winter.

Model predictions concerning the habitat preferences of Golden Eagles also fit the situation in the Bavarian Alps very well. In only a few cases were areas utilized by the eagles not predicted, and some of these represented very special, maybe unique situations in areas in prealpine marshlands where eagles hunt roe deer (*Capreolus capreolus*).

Validation was done by local experts using the same procedures in two test areas: South Tyrol, Italy and the Grisons, Switzerland. Both areas provided similar results showing high correspondence of the habitat-quality predictions. The possibility of identifying "hot-spots" or areas with high habitat quality as well as high settlement density in the eastern Alps was tested for the Grisons, Switzerland and finally for all of Switzerland by calculating settlement-density-models (SDM). SDMs predict settlement density on a scale from low to very high. Comparison of the models with real data showed good correspondence with >95% of 106 actual home range centers (the preferred nest site location of one breeding pair) in the Grisons and 310 breeding pairs within predicted areas of high and very high settlement density in Switzerland. Small differences between reality and the SDM were analyzed by investigating the impact of skiing facilities on the spatial distribution of eagle pairs and their potential prey species. Some of these differences were related to the presence of skiing facilities and some were not.

Cooperation in Nature Conservation. After establishing close cooperative relationships between conservationists and user groups in 1995, no further human-induced brood failures were documented in the study area. Breeding success increased during the project period from 0.18 young per pair/yr from 1982–87 (Schöpf 1989) to 0.26 young per pair/yr from 1994–2000 (Brendel et al. 2000).

In 1998, one eagle pair started breeding very close to a military helipad. The routes used by the helicopters were changed immediately and the pair bred successfully. Disturbances within 300 m ("primary zones") of nesting Golden Eagles were also avoided during the International Bavarian Paraglider Championships held in Berchtesgaden in 1998 through the cooperation between the organizing committee and the National Park administration to fix routes used during the competitions. The use of permanent blackboards for paragliders in the study area was received very positively. Because of this, a project to use this strategy in other areas of the Bavarian Alps with a similar degree of human pressure has already been proposed.

Environmental Education. Almost 50 000 people have visited the Golden Eagle exhibit and have used the "experience trails" since their establishment in 1998. Hundreds of tourists each year take part at the guided Golden Eagle tours to see this fascinating species in Berchtesgaden. Surveys as well as official visitor statistics show a high degree of approval for these programs.

DISCUSSION

The Golden Eagle population appears to be at capacity in many parts of the European Alps (Brendel 1998). Self-regulation by intraspecific competition is widespread among various populations in Switzerland (Jenny 1992) and possibly in many other regions. Nevertheless, it is a latent Endangered Species in the European Alps (Bauer and Berthold 1996, Haller 1996). Human disturbances close to nests (Bezzel and Prinzinger 1990), disturbances of prey species in their preferred habitats, as well as human-related changes in the spatial ex-

tent of its hunting areas might threaten the alpine population in the future (Brendel et al. 2000). Persecution might also become a factor in the future if protection laws in regions in Austria are changed to allow eagles to be controlled. To secure the population of Golden Eagles in the European Alps in the future, the following requirements must be met: (1) no persecution of Golden Eagles should be allowed throughout the year; (2) habitats essential for Golden Eagles must be identified and conserved throughout its entire alpine range; and (3) disturbances within the "primary zone" around nest sites must be avoided during the sensitive period from March until July.

GIS analysis has already proved to be a useful tool for investigating the habitats of large eagles (Chandler et al. 1992). The identification and evaluation of essential habitats using GIS is an essential step toward understanding the distribution mechanisms of raptors in large areas, like the European Alps. Differences between model-prediction and real habitat preferences will have some importance for local conservation, but will have a negligible effect on conclusions over a larger area. Different settlement densities of the alpine eagle population can also be predicted by implementing the factor "landscape compartments." These distributional "hot spots" might be potential source areas that could compensate for other parts of the range that are in poor or deteriorating condition. Data from the population in Berner Oberland, Switzerland support this hypothesis (Jenny 1992). Assuming that prey abundance is not a limiting factor in the Alps, differences in the sizes of home ranges of breeding pairs (Bezzel and Fünfstück 1994, Zechner 1995, Haller 1996) seem to be simply a product of the predominant geomorphological structure (Brendel et al. 2000).

Habitat suitabilities during winter and summer are related to the amount and availability of thermal updrafts, the availability of prey (carrion, live prey), and the interaction between them in early spring. Models concerning these differences in habitat suitability can provide a better understanding of the importance of thermal "stepping stones" (i.e., slopes that provide good thermal updrafts and their spatial distribution in an area or home range), which might be an important factor in overall habitat quality. This and the availability of food during winter are probably the most important factors for determining whether eagles will be able to breed in the next year (Brendel et al. 2000). These parameters can be modeled relatively easily using GIS (Bögel and Eberhardt 1997) and might help to predict tendencies in breeding performance of well-known populations.

The impact of human activities like paragliding on the behavior and energy budgets of alpine mammals such as chamois (*Rupicapra rupicapra*) has been extensively discussed (Zeitler 1995). The effects of paragliding on the breeding performance of cliff-nesting raptors like Golden Eagles are rarely considered. It is difficult for pilots and climbers to avoid disturbances by maintaining fixed distances from nests. Habituation of birds to this form of disturbance has not been documented making it impossible to set an objective distance for all situations. A distance of 300 m for paragliders, climbers, and hikers and 500 m for helicopters appears to be reasonable in decreasing breeding failure caused by these activities. The increase in breeding success during the studies in Berchtesgaden was probably not caused exclusively by cooperation strategies, but they may have played an important part in the increase. Changing human behavior by training pilots about conservation issues appears to be a very effective way of reducing disturbances within 500 m of breeding sites. Risk maps for helicopters or permanent blackboards for paragliders complete this successful strategy and provide a higher acceptance among sportsmen and other users than simple prohibitions or extensive regulations (Brendel et al. 2000).

The efficiency of environmental education strategies, like exhibits or "experience trails" is very difficult to measure, but counting the number of visitors who use them can be an appropriate tool to estimate their success.

CONCLUSIONS

Due to its importance as an environmental indicator for areas of open land (Plachter 1990), the Golden Eagle provides many new and interesting tasks for GIS-modeling in connection with future conservation management of alpine landscapes. Calculation of three-dimensional use patterns of home ranges by eagles could be helpful in providing a more detailed explanation of their different distribution patterns in its alpine range. In the future, work using this approach would be facilitated by the construction of a uniform database for the whole of the Alps to be used within a GIS model.

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THE STATUS OF THE GOLDEN EAGLE (*AQUILA CHRYSAETOS*) IN POLAND

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Abstract.—The Golden Eagle (*Aquila chrysaetos*) is a very rare breeding species in Poland and it is included in the Polish Red Data Book. At the end of twentieth century, only 30–35 pairs were nesting in the country. It has had protected species status for several decades and its nests have also been protected since 1984. All types of human disturbance are forbidden within a radius of 200 m of nests throughout the whole year and all forestry activity is forbidden within a radius of 500 m of nests between 1 February and 31 August. This report presents the results of the activities of Eagle Conservation Committee (KOO) members.

Key Words: *Golden Eagle*; Aquila chrysaetos; *Poland*; *Carpathian Mountains*; *repopulation.*

El estado de el águila real (*Aquila chrysaetos*) en Polonia

Resúmen.—El águila real (*Aquila chrysaetos*) es una especie reproductiva muy rara en Polonia y esta incluida en el Libro Royo po Laco polaco. Al final del siglo veinte, únicamente 30–35 parejas estaban anidando en el país. Esta ha tenido estatus de especie protegida por algunas décadas y sus nidos además han sido protegidos desde 1984. Todos los tipos de disturbios humanos están prohibidos dentro de un radio de 200 m de los nidos a través de todo el año y toda actividad forestal esta prohibida en un radio de 500 m de los nidos entre el 1 de febrero y el 31 de agosto. Este reporte presenta los resultados de las actividades de los miembros del Comité de Conservación del Aguila (KOO).

[Traducción de César Márquez y Victor Vanegas]

Historical Distribution in Poland

Information on the early distribution of the Golden Eagle comes from excavations where eagle bones have been found in old human settlements from the Stone Age, Iron Age, and Middle Ages (Wyrost 1994). Until the 19th century, the Golden Eagle most likely inhabited the whole country of Poland. As a result of human persecution, its numbers decreased dramatically and by the middle of the 19th century, there were estimated to be only 50 pairs remaining (Król 1992). It gradually became extinct in various parts of Poland. For example, the last Golden Eagles in southwestern Poland in Silesia were recorded in 1845 in the Karkonosze Mountains (Martini 1926), the Kurpiowski Forest in 1859 (Taczanowski 1860), the Gorzowskie District of western Poland in 1874 (Schalow 1919), the Mazurian Lakes region of northeastern Poland in 1882 (Tischler 1941), and the Pomeranian Region in 1887 (Neithammer 1938). By the end of the 19th century, nesting sites remained only in the Carpathian Mountains, where up to dozen pairs nested (Król 1992).

At the beginning of the 20th century, all information about breeding of this species came from the area of the Carpathians. However, in the 1930s and 1940s, Golden Eagles were recorded in northeastern Poland (Tischler 1941). In the 1950s and 1960s, the Polish population of Golden Eagles was estimated to be between 20–30 pairs, half of which inhabited northeastern Poland (Król 1992). In the 1970s, a few new sites were recorded, including a breeding site in the Kozieniecki Forest in central Poland (Cieślak and Piasecki 1981), and probably new breeding sites in the Barycz Valley, Niepolomicki Forest, and Gorzowskie District (Tomiałojć 1990). In the late 1970s and early 1980s, eagles abandoned some of these areas, mainly in northeastern Poland where they disappeared in the Carpathian Mountains (Tomiałojć 1990, Król 1992). By the mid-1980s, probably only 10 pairs continued to breed in Poland (Tomiałojć 1990).

Surveys conducted by the Eagle Conservation Committee (KOO) in the late 1980s provided new information on locations of single nesting pairs in northeastern and eastern Poland. At that time, the total number of Golden Eagles in Poland was es-

Table 1. Number of distribution of breeding Golden Eagles (*Aquila chrysaetos*) in Poland at the end of the 1990s (Komitet Ochrony Orłow 1993, 1994, 1995, 1996, Adamski et al. 1999).

Geographical Region	Number			Source
	Occupied Territories	Probable Occupied Territories	Single Observations	
Mazury Lake District	1	0	2	M. Mellin, H. Hut, M. Stajszczyk, pers. comm.
Chelminsko-Dobrzynskie Lake District	0	0	1	L. Kleinschmidt, R. Krupa, S. Guentel, T. Rafalski, pers. comm.
Koszalin Seacoast	1	0	1	K. Wypychowski, B. Kotlarz, pers. comm.
North Podlaska Plain	1	1	0	J. Skoczynska, E. Pugacewicz, pers. comm.
Radom Plain	0	0	1	Furmanek and Osojca (1996)
Silesian Plain	0		1	H. Koscielny, pers. comm.
Carpathians	22	3	4	Stój et al. (1997)
Total	25	4	10	
Estimated numbers			30–35	

timated to be 15 pairs (Król 1992). In the first half of the 1990s, the breeding population continued to decline and only 5–10 pairs were recorded (Tucker et al. 1994).

Present Distribution and Numbers in Poland

The information on breeding by Golden Eagles in Poland in the Carpathians led to the creation of a new program in 1993 called "Protection of Eagles and Other Rare Species of Birds of Prey" that was conducted by KOO. The program was established to estimate the distribution and number of breeding pairs in the Golden Eagle population, to assess the condition of breeding populations by describing breeding parameters, and to find nests and implement protection zones around them.

Pairs of eagles and nests were found in various ranges of the Carpathians including the Tatras, Pieniny Mountains, Low Beskidy Mountains, Sadecki Mountains, Bieszczady Mountains, Sanocko-Turczanskie Mountains, and Przemyskie Plateau (Table 1). One pair was also found in the Biebrza River valley in northeastern Poland. The most significant finding of the program was a new breeding pair found on the Baltic coast in the Slovinski National Park which had not supported breeding Golden Eagles for over 100 yr (Chrzanowski 1992). The distribution of pairs was irregular and restricted to areas with low human populations, extensive agriculture, and pristine or nearly-pristine ecosystems.

At present, the Golden Eagle is most abundant in the Carpathians where about 85% of the Polish population is concentrated. The size of the Carpathian population is estimated at 22–25 pairs (22 occupied and 3 probably occupied territories) with a density of 0.33–0.38 pairs/100 km^2. If observations of eagles not exhibiting territorial behavior are included, the Carpathians may hold 25–30 pairs giving an average population density of 0.38–0.45 pairs/100 km^2.

Apart from the Carpathians, 3–4 pairs (3 occupied territories and 1 probably occupied territory) were found in the northern and northeastern parts of Poland, in extensive wet meadows and marshes in river valleys located close to old forests. Both hunting and breeding areas are located in remote areas with low human pressure.

The size of the Polish Golden Eagle population is now estimated at 30–35 pairs (Stój et al. 1997). This is the highest number found in the last 50 yr. Based on data from Król (1992), it appears that this increase in the breeding population has occurred in various parts of the Carpathians including the Bieszczady Mountains where the population, previously estimated at 4–7 pairs, increased by 75% and in the Beskid Niski Mountains where the population increased from one to six breeding pairs.

In contrast, there has been a marked decrease

in the population in northeastern Poland. In the 1950s and 1960s, over half of the Polish population of Golden Eagles inhabited this region but, today, only 10–15% exists in the region. The decline has probably been caused by human disturbance resulting from an increase in the human population density and a change in the management of open areas.

Breeding success of the Golden Eagle in Poland is relatively high enabling the population to maintain its numbers. About 47% (N = 51) of nests produce young. This productivity is similar to that of eagle populations in other European countries and higher than that found in Czech Republic, Slovakia, and the Alps (Kornan 1995, Kornan et al. 1995, 1996). In Poland, the average number of nestlings per breeding pair is 0.55 (N = 28), which should also be sufficient to maintain the population size. The number of fledglings per successful brood is 1.17, which is also rather high in comparison to other countries in Europe (Dennis et al. 1984, Bezzel and Fünfstück 1994, Kropil and Majda 1996, Randla and Tammur 1996, Zocchi and Panella 1996). As many as 20% of pairs produce 2 fledglings when there is no human interference.

DANGERS TO THE POPULATION

Threats to the Golden Eagle population in Poland include illegal hunting and killing of eagles for taxidermy, loss of hunting areas, harassment of eagles in their hunting areas and breeding sites, loss of suitable nesting areas, vertical structures in the landscape such as electric power lines, and pesticide and heavy metal contamination.

Despite these dangers, the overall condition of the Polish population of Golden Eagles in the Carpathians is good considering its high productivity and abundant food supply (Cramp and Simmons 1980).

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THE PROTECTION OF EAGLES AND THE BALD AND GOLDEN EAGLE PROTECTION ACT

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ABSTRACT.—The Bald Eagle Protection Act of 1940 (16 USC 668–668d) was passed to curb the wanton destruction of Bald Eagles (*Haliaeetus leucocephalus*). In 1962, prohibitions against enumerated acts were extended to the Golden Eagle (*Aquila chrysaetos*). The Golden Eagle continues to be impacted by poisonings from predator control, urban sprawl, and increased recreational use of remote areas. With the proposed removal of the Bald Eagle from the protection of the Endangered Species Act, the Bald and Golden Eagle Protection Act will be subject to increased scrutiny. The Fish and Wildlife Service is examining the use of Bald Eagle management guidelines to avoid take under the Eagle Act. Similar guidelines along with a broad outreach program would be appropriate for the Golden Eagle to avoid take at nest sites.

KEY WORDS: *Bald Eagle; Golden Eagle;* Haliaeetus leucocephalus; Aquila chrysaetos; *Bald Eagle Protection Act; Bald and Golden Eagle Protection Act; conservation.*

La Ley de Protección de las Aguilas Real y de Cabeza Blanca

RESÚMEN.—La Ley de Protección del Aguila de Cabeza Blanca de 1940 (16 USC 668–668d) fue aprobada para detener la destrucción desenfrenada del símbolo nacional de los EE.UU. En 1962, la protección de esta ley fue extendida al águila real. El águila sigue siendo impactado por tales cosas como venenos antideprededores, la extensión urbana, y el aumento del uso recreacional de áreas remotas. La Ley de Protección de las Aguilas Reales y de Cabeza Blanca estará sujeta a un escrutinio creciente debido a la propuesta exclusión del águila de cabeza blanca de La Ley de Especies en Peligro. El Servicio Norteamericano de "Fish and Wildlife" propondrá guías de cuidado del águila de cabeza blanca para evitar su molestia o muerte bajo la ley. Guías similares junto con un programa de educación pública serían apropiados para evitar la molestia del águila real.

[Traducción del autor]

Protection of nesting Golden Eagles (*Aquila chrysaetos*) and Bald Eagles (*Haliaeetus leucocephalus*) is crucial to their survival. Due to their low fecundity, loss of individuals can have significant impacts on the stability of populations (Grier 1980). In the U.S., the need for legal protection of raptors has been recognized since the turn of the century.

Eagles have inhabited this planet for centuries. Golden Eagle remains have been dated to a half million years ago and Bald Eagle remains have been found dating back 10 000–12 000 years and it likely existed much earlier (Emslie 1998). For as long as humans have had contact with eagles, they have revered them. Many Native American cultures still hold eagles in spiritual regard. This is true for both northern and southern cultures. Today, the Golden Eagle is the national symbol of Mexico just as the Bald Eagle is the national symbol of the U.S.

Eagles have also been widely persecuted. Shooting was a common problem at the turn of the 20th century. In 1888, B. Evermann from Illinois was quoted as saying, "Scarcely does an eagle come into our state now and get away alive, if he tarry more than a day or two" (Mattsson 1988). Alaska initiated a bounty on Bald Eagles in the first half of the century resulting in the reported deaths of 128 000 Bald Eagles. From 1950 to the mid-1960s, Texas ranchers shot eagles from airplanes killing an estimated 20 000 eagles (Gerrard and Bortolotti 1988). Poison-baiting for predator control has been a significant source of mortality for eagles and continues to be a problem today. Electrocution is another source of mortality which has decreased due to better wiring practices, but it remains a problem in many areas.

The U.S. began to legally address the loss of migratory birds in 1918 with the passage of the Mi-

gratory Bird Treaty Act. One focus was the protection of birds from the feather trade for hats. This act was amended in 1936 to implement the Migratory Bird and Game Mammal Treaty with Mexico (50 Stat. 1311; TS 912). The treaty adopted a system for the protection of certain migratory birds in the U.S. and Mexico. It allows, under regulation, the rational use of certain migratory birds; provides for enactment of laws and regulations to protect birds by establishment of closed seasons and refuge zones; prohibits the killing of insectivorous birds, except under permit when harmful to agriculture; and provides for enactment of regulations on transportation of game mammals across the U.S.-Mexican border. Signed in Mexico City on 7 February 1936, this treaty was ratified by the president of the U.S. on 8 October 1936 and documents of ratification were exchanged on 15 March 1937 in Washington, D.C. Implementation of the treaty was accomplished by amending the Migratory Bird Treaty Act of 1918 (USC 703–711; 40 Stat. 755) on 20 June 1936 (49 Stat. 1556). The treaty was amended 10 March 1972 (23 U.S.T. 260; T.I.A.S. 7302) to add 32 additional types of birds including eagles, hawks, owls, and corvids. Similar treaties were signed with Canada (1916), Japan (1974), and Russia (1978). With the passage of the Migratory Bird Treaty Act, the widespread destruction of birds for commercial purposes eased, but the persecution of eagles continued in many areas.

On 8 June 1940, the U.S. Congress passed the Bald Eagle Protection Act (16USC 668a–668c; 50 CFR 22) with the specific purpose of protecting the national symbol. The enacting clause of this act provided:

> "Whereas the Continental Congress in 1782 adopted the Bald Eagle as the national symbol; and
> "Whereas the Bald Eagle thus became the symbolic representation of a new nation under a new government in a new world; and
> "Whereas by that act of Congress and by tradition and custom during the life of this Nation, the Bald Eagle is no longer a mere bird of biological interest but a symbol of the American ideals of freedom; and
> "Whereas the Bald Eagle is now threatened with extinction:
> Therefore
> "Be it enacted . . . ," etc.

Since its passage, the Bald Eagle Protection Act has been strengthened and, in 1962, it was amended to include Golden Eagles. There are several articles of this act which give it broader authorities than the Migratory Bird Treaty Act. The Eagle Act defines "take" more broadly than that of the Migratory Bird Treaty Act and includes pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb. The U.S. Fish and Wildlife Service is currently exploring the use of management guidelines as technical assistance to avoid take as defined under the Eagle Act.

The Eagle Act does not require an action to be done "knowingly" but may be enforced for actions taken "with wanton disregard for the consequences of his act." Therefore, carelessness is not an adequate defense against taking of eagles. Another provision of the act is that it allows for rewards to the person who provides information that leads to a conviction under the act. The reward is up to one half the fine, not to exceed \$2500. This can be a powerful tool if knowledge of the reward can get out to the public to use it. The Eagle Act also has a provision for cancellation of grazing rights on federal lands for violators of the act. Maximum fines are similar to those under the Migratory Bird Treaty Act with a \$250 000 fine per individual and a \$500 000 fine per organization and/or two years imprisonment.

The protection of eagles requires some knowledge of what needs protection. Nesting management guidelines for eagles are now quite well-known. For bald eagles, protective zones are described as a minimum of about 100 m for the primary protective zone and about 200 m for the secondary zone (U.S. Fish and Wildlife Service 1983). Guidelines for Golden Eagles are not as well-defined as for Bald Eagles. Typically Golden Eagles occur in open country and require a minimum of 300 m around their nests for a protective zone (Suter and Jones 1981). Many sets of guidelines have been developed and vary regionally with some describing tertiary zones for management.

While it is certainly true that the guidelines need to be adequately protective and that circumstances vary in which more or less buffer may be needed; however, they may be useless if people do not comply. Public outreach is a crucial aspect of eagle management and protection that cannot be ignored. Good laws and sound management plans lose their effectiveness if no one knows about them.

Fortunately, communication is easier today than

ever before, but still remains a sizeable task. This responsibility must be shared with the general public. Livestock farmers need to be given information to help them employ clean practices to minimize conflicts with eagles on their lands. Developers need guidelines to minimize impacts and to be able to promote the conservation of eagles as value added to their properties. Conservation groups should be tapped to help disseminate information on eagle management. People need to be aware of eagles and develop a protective attitude toward them in order for an eagle protection to be a success.

In summary, I recommend the reporting of legal violations related to eagles, that we exercise extensive outreach to educate landowners and land managers about eagles and their needs, and finally that we take these efforts to all levels of government and land ownership including the most local levels.

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GOLDEN EAGLES IN THE U.S. AND CANADA: STATUS, TRENDS, AND CONSERVATION CHALLENGES

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ABSTRACT.—We reviewed the literature to assess status and population trends and to identify mortality factors affecting Golden Eagle populations in the U.S. and Canada. Nesting populations in Alaska and Canada are stable, but some nesting populations in the western U.S. have declined. Small but steady declines in the intermountain West have been associated with shrub loss and declining jackrabbit populations; declines in southern California have been attributed to urbanization. Migration counts in the eastern U.S. suggest a decline in Golden Eagles from the 1930s to the early 1970s, with a stable or increasing trend since the early 1970s. No significant trends in migration counts were reported for Golden Eagles in the western U.S. since the mid-1980s. Western migration count sites on the continental divide in the Rocky Mountains at or just north of the U.S.-Canadian border (49–51°N latitude) show potential to provide information on trends of Golden Eagle populations from Alaska and western Canada. Most eagle mortality is human related. This paper illustrates the need for more effective monitoring of Golden Eagle populations in North America.

KEY WORDS: *Golden Eagle;* Aquila chrysaetos; *status; monitoring; mortality; U.S.; Canada.*

Aguilas reals en E.U.A. y canadá: estado, tendencias y retos para su conservación

RESÚMEN.—Revisamos la literatura para evaluar el estado y las tendencias poblacionales y para identificar los factores de mortalidad que afectan las poblaciones de águila real en E.U.A. y Canadá. Las poblaciones que anidan en Alaska y Canadá están estables, pero algunas poblaciones que anidan en el oeste de E.U.A. han declinado. Pequeñas, pero continuas declinaciones en el oeste íntermontañoso han sido asociadas con la perdida de arbustos y con el decline en las poblaciones de liebres; el declive en el sur de California ha sido atribuido a la urbanización. Conteos migratorios en el este de E.U.A. sugieren un decline en las águilas reals desde los años 1930s hasta principios de los 1970s, con una tendencia estable o a incrementar desde el principio de los 1970s. Ninguna tendencia significativa en conteos de migratorios fue reportada para las águilas reals en el oeste de E.U.A. desde mediados de los 1980s. Los sitios de conteo de migración del oeste sobre la divisoria continental en las montañas rocosas en o justo al norte de la frontera E.U.A.-Canadá (49–51° latitud N) tiene potencial para proveer de información sobre las tendencias de las poblaciones de águilas reals de Alaska y el oeste de Canadá. La mayoría de la mortalidad de las águilas esta relacionada con los humanos. Este articulo ilustra la necesidad de un monitoreo mas efectivo de las poblaciones de águila real en Norte América.

[Traducción de César Márquez y Victor Vanegas]

Until recently Golden Eagles (*Aquila chrysaetos*) were considered abundant in North America with stable populations (Hamerstrom et al. 1975, Palmer 1988). However, some studies, particularly those from migration count sites in the U.S. (e.g., Bednarz et al. 1990, Hoffman et al. 1992), have raised questions about trends of Golden Eagle populations. Only four nesting Golden Eagle pairs are known in the eastern U.S in Maine, Tennessee, and Georgia with two pairs the result of introduction efforts in Tennessee and Georgia (Kochert et al. 2002). In addition, recent requests by Native Americans to the U.S. Fish and Wildlife Service to harvest Golden Eagles for religious purposes have prompted the need to assess the status of the species in North America and to assess threats to populations (Bart et al. 1999). In this paper, we report information on the status and trends of Golden Eagle populations in the U.S. and Canada, and we discuss mortality factors affecting eagle populations.

METHODS

We obtained information from published and unpublished literature and personal interviews with individuals

Table 1. Trends in number of occupied nesting territories at four long-term survey areas in the U.S.

LOCATION	YEARS	N^a	TREND	SOURCE
Interior Alaska	1988–99	58–76	Stable	McIntyre and Adams 1999, McIntyre 2001
Southwestern Idaho	1971–99	28–35	Decline*	Steenhof et al. 1997, USGS, unpubl. data
Northeast Colorado	1972–90	7–10	Decline	Leslie 1992
Southern California	1895–1999	40–85	Decline	Bittner and Oakley 1999

[a] Number of territories.
* $P < 0.001$.

conducting long-term surveys of Golden Eagles. We used a variety of data including long-term nesting surveys, the Breeding Bird Survey (Peterjohn 1994), Christmas Bird Counts (Sauer et al. 1996), and migration counts. Other sources included modeling efforts and other literature syntheses.

To assess long-term trends in territory occupancy and productivity, we selected studies that spanned more than 10 yr and extended into at least the mid-1980s. Four studies fit the criteria for occupancy (Table 1), and four fit criteria for productivity (Table 2). Continuous studies of both occupancy and productivity occurred only in the Snake River Birds of Prey National Conservation Area (NCA) in southwestern Idaho (Steenhof et al. 1997, USGS unpubl. data) and in Denali National Park in interior Alaska (McIntyre and Adams 1999, McIntyre 2001). Occupancy data from San Diego County, California span more than 100 yr and were collected by several investigators (Bittner and Oakley 1999), including Dixon (1937) and Scott (1985). Leslie (1992) compared occupancy in northeastern Colorado during two seasons 18 yr apart. We obtained productivity information for Utah from Keller and Smith (1998) and Bates and Moretti (1994) (Table 2). In addition, we used the number of egg-laying pairs during 20 seasons in central Oregon (Anderson 1985).

RESULTS

Nesting Territory Occupancy. Of four areas tracked for long-term occupancy of eagle territories, all except interior Alaska experienced declines (Table 1). The number of occupied territories in southwestern Idaho declined significantly between 1971 and 1994 ($r^2 = -0.54$, $P < 0.001$; Steenhof et al. 1997). Declines of nesting eagles in southwestern Idaho were associated with loss of shrubs and black-tailed jackrabbit (*Lepus californicus*) habitat due to widespread fires (Kochert et al. 1999). Nesting eagles in San Diego County decreased dramatically from an estimated 85 pairs in 1900 to 40 occupied territories in 1999 (Bittner and Oakley 1999). Large-scale declines occurred between 1956–80, and subtle declines occurred through 1999. These declines were related to extensive residential development (Bittner and Oakley 1999). The decline reported for northeastern Colorado (10 to 7 pairs) should be interpreted with caution because of the small sample size and low frequency of sampling (Leslie 1992). The number of nesting attempts in central Oregon declined significantly ($r^2 = -0.69$, $P < 0.001$) between 1966–84 (Anderson 1985). It is not clear if this decline was the result of a decrease in occupancy or in the proportion of pairs that laid eggs.

Eagle Productivity. In contrast to territory occupancy, no long-term trends in productivity were reported except in north-central Utah (Table 2).

Table 2. Trends in Golden Eagle productivity in four long-term survey areas in the U.S. Productivity is young fledged per pair except for north-central Utah where it is young per egg-laying pair.

LOCATION	YEARS	N	TREND	SOURCE
Interior Alaska	1988–99	58–76	None	McIntyre and Adams 1999, McIntyre 2001
Southwestern Idaho	1971–99	28–35	None	Steenhof et al. 1997, USGS unpubl. data
North-central Utah	1977–98	31–240	Decline*	Keller and Smith 1998
Eastern Utah	1981–92	39	None	Bates and Moretti 1994

* $P = 0.02$.

Table 3. Golden Eagle trends from Breeding Bird Surveys, 1966–98.

REGION	TREND	N^a	P
All U.S.[b]	2.4	271	0.23
Pacific region	4.3	99	0.17
Southwest region	−6.6	21	0.25
CMP[c]	2.8	151	0.36
Canada	−7.1	5	0.56
Survey wide	1.9	276	0.33

[a] Number of routes with eagle observations.
[b] Excluding Alaska.
[c] Central mountains and plains.

Table 4. Golden Eagle trends from Christmas Bird Counts, 1959–88.

REGION	TREND	P
Survey wide	−1.0	<0.05
States with declines		
Idaho	−1.4	<0.001
Oregon	−2.4	<0.001
Kansas	−3.7	<0.05

Although eagle productivity has fluctuated with changes in the major prey in Alaska, southwestern Idaho, and eastern Utah, the number of the young fledged per occupied territory showed no trends over time (Bates and Moretti 1994, Steenhof et al. 1997, McIntyre and Adams 1999). However, the proportion of young fledged per egg-laying pair declined slightly but significantly ($r^2 = -0.22$, $P = 0.02$) in the desert (lower elevation) study area of north-central Utah (Keller and Smith 1998). This decline in productivity may reflect loss and degradation of native sagebrush (jackrabbit) habitats (Keller and Smith 1998).

Breeding Bird Surveys. Breeding Bird Surveys (BBS) show no trend for nesting Golden Eagles on either a regional or continental scale from 1966–98 (Table 3). Long-term data from BBS routes are available only in the southern portions of the Canadian provinces, and these results may not be reliable because only five routes had eagle observations (Table 3). Data from Alaska and the Yukon and Northwest Territories of Canada where Golden Eagles are abundant (Kirk and Hyslop 1998, McIntyre 2001) were not included in these analyses because BBS did not establish routes in these regions until the 1980s (Peterjohn 1994) and the number of routes and routes with eagle sightings are low. Most BBS routes follow roads (Peterjohn 1994) and because Golden Eagles generally nest in remote areas (Palmer 1988), the BBS is not the most reliable method to assess trends of nesting Golden Eagles.

Trends Based on Other Information. Golden Eagle nesting populations and productivity in Canada are likely stable; evidence for this assessment includes considerable unpublished information (Kirk and Hyslop 1998). In eastern Canada, nesting populations have been found recently at Hudson Bay in northern Quebec (Morneau et al. 1994) and in the Labrador Peninsula. Nesting populations in southwestern Saskatchewan and the Yukon Territory are stable, with the latter being a large population (estimated 900–1000 pairs). Long-term productivity of eagles in the Northwest Territories is also stable (Kirk and Hyslop 1998). White (1994) reported that the status of Golden Eagles in the western U.S. was variable: stable in some areas and possibly declining in others. Hunt et al. (1999) modeled the breeding Golden Eagle population at Altamont Pass in central California and concluded that the population was either stable or decreasing.

Winter Surveys. According to results of Christmas Bird Counts, Golden Eagles declined significantly throughout the U.S. and Canada (Ontario and British Columbia) from 1959–88 (Table 4). Counts in Idaho, Oregon, and Kansas declined significantly, while other survey regions showed no significant trend. However, Christmas Bird Counts have limited value for detecting Golden Eagle trends because of the low number of individuals counted on each survey, inconsistencies among years in survey efforts and area surveyed, and the fact that most surveys are in suburban, exurban, or rural settings where eagles are least likely to occur.

Aerial surveys coordinated by the U.S. Fish and Wildlife Service (USFWS) provide potentially useful information on wintering Golden Eagle densities and adult:immature ratios (USFWS unpubl. data). Between 1972–80, 124 000 km² were sampled from random transects in Colorado, Idaho, Montana, New Mexico, Utah, and Wyoming during January–February. Only the area in southern Idaho was surveyed after 1980 and for more than 10 yr (Kochert et al. 1984). This 18 000-km² area was also surveyed in October from 1972–78. Counts averaged 2.56 more eagles during midwinter than in October, suggesting an influx of migrant birds. The southern Idaho area contained both resident

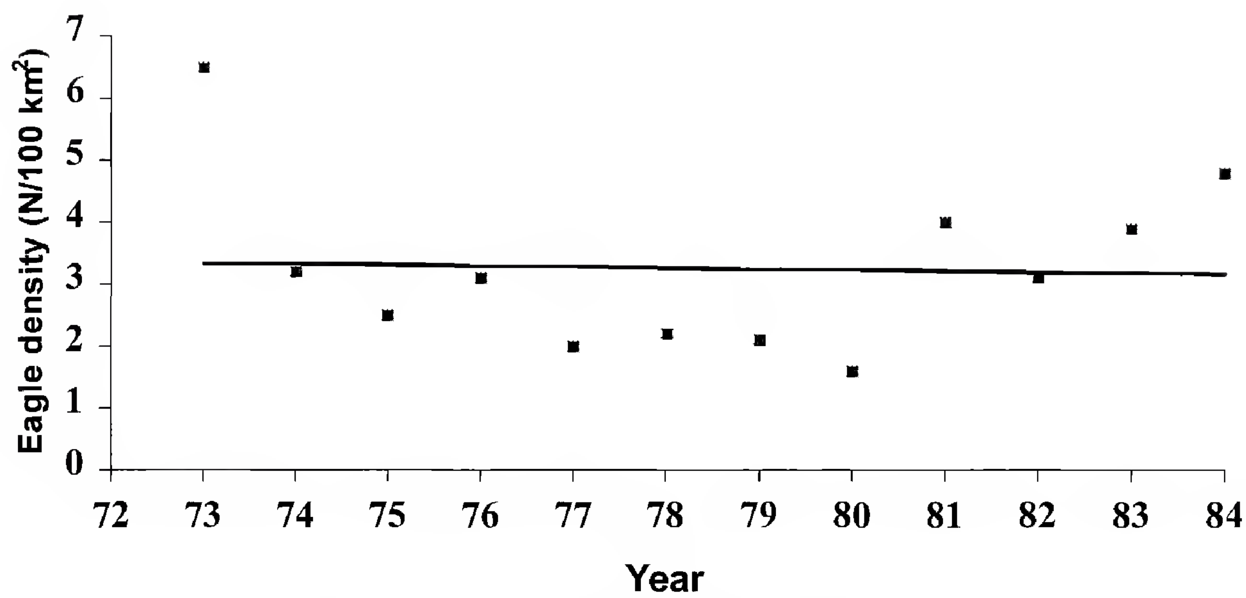

Figure 1. Densities of Golden Eagles wintering in southern Idaho, 1973–84.

birds and migrants from Alaska and Canada during the winter (Fuller et al. 1995, Craig and Craig 1998, McIntyre 2000). Wintering densities in southern Idaho correlated strongly with black-tailed jackrabbit abundance (Kochert 1980). Because jackrabbit populations cycle about every 10 yr (Johnson and Peek 1984), inferences from data sets covering less than 10 yr can be misleading. Eagle counts from 1973–80 showed a significant decline in southern Idaho ($r = -0.80$; $P = 0.02$) that coincided with a jackrabbit decline (Kochert 1980), but longer-term analyses that included the jackrabbit recovery showed that winter eagle densities were stable from 1973–84 (Fig. 1).

Migration Count Sites in the Eastern U.S. and Canada. We assessed trends of migrating Golden Eagles in the eastern U.S. and Canada from six migration count sites (Table 5). Passage rates (number of Golden Eagles per 10 hr of observation) declined significantly at Hawk Mountain, Pennsylvania between 1934–72 but remained relatively stable between 1973–86 (Bednarz et al. 1990). From 1987–99, trends for Golden Eagles at Hawk Mountain have been stable or increasing (L. Goodrich pers. comm., Hawk Mountain Sanctuary unpubl. data). Data from Ontario (Hussell and Brown 1992) and five migration sites in the eastern U.S. (Titus and Fuller 1990) suggest at least a stable trend for Golden Eagle counts from the early 1970s to the late 1980s.

Migration Count Sites in the Western U.S. and Canada. Unlike migration count sites in the eastern U.S., continuous counts in the western U.S. span little over a decade (Table 6). Passage rates at four migration count sites showed no trend from the mid-1980s to late 1990s (Table 6). These sites occur south of 42°N latitude, and eagles that pass through them are probably a mix of northern migrants and dispersing resident birds or short-distance migrants (J. Smith pers. comm.). These Hawkwatch International sites report possible changes in eagle age ratios that may reflect deteriorating conditions in the western U.S. (J. Smith pers. comm.). Passage rates of immature Golden Eagles at the Wellsville Mountains in northern Utah were significantly lower from 1987–97 than from 1977–79.

Raptor migration count sites on the continental divide in the Rocky Mountains just north of the U.S.-Canadian border show potential for monitor-

Table 5. Golden Eagle trends at migration count sites in the eastern U.S. and Canada.

LOCATION	YEARS	SEASON	TREND	SOURCE
Hawk Mountain, Pennsylvania	1934–72	Autumn	Decline	Bednarz et al. 1990
	1973–86	Autumn	None	Bednarz et al. 1990
Niagara Peninsula, Ontario	1975–90	Autumn	Increase	Hussell and Brown 1992
5 Eastern U.S. sites[a]	1972–87	Autumn/Spring	None	Titus and Fuller 1990

[a] Includes Hawk Mountain, Pennsylvania; Hawk Ridge, Minnesota; Whitefish Point, Michigan; Derby Hill, New York; and Cape May, New Jersey.

Table 6. Golden Eagle population trends at four migration count sites in the western United States.[a]

LOCATION	SEASON	YEARS	TREND
Wellsvilles, Utah	Autumn	1987–97	none[b]
Goshutes, Nevada	Autumn	1983–97	none
Manzanos, New Mexico	Autumn	1985–97	none
Sandias, New Mexico	Spring	1985–98	none

[a] Source: Hoffman et al. unpubl. data, J. Smith, pers. comm.
[b] Passage rates for immatures were significantly lower from 1987–97 than from 1977–79.

ing trends because of the large number of eagles that pass over them (Sherrington 1993). For example, fall counts at Mount Lorette (50°58′N) in southern Alberta averaged 4014 Golden Eagles (range 3706–4599) between 1993–96, and spring counts averaged 3707 (range 2461–4213) between 1993–98 (Sherrington 1998, 1999). Although counts have been conducted since 1984 at Windy Point (50°40′N) and 1992 at Mount Lorette (Sherrington 1998), data have not been analyzed for trends.

Conservation Challenges. The greatest conservation challenge in managing Golden Eagle populations is offsetting the adverse effects of human activity. Of Golden Eagles found dead from the early 1960s to the mid-1990s, 73% died from human-related causes, including accidental trauma (27%), electrocution (25%), shooting (15%), and poisoning (6%; Franson et al. 1995). Accidental trauma included collisions with cars, fences, wires, and wind turbines. At least 28–43 Golden Eagles are killed each year by turbine blade strikes in the Altamont Pass Wind Resource Area in west-central California; of 61 eagle deaths investigated in the Diablo Range between 1994–97, 37% resulted from turbine strikes, 5% from car strikes, and 3% from fence collisions (Hunt et al. 1999). Golden Eagles continue to be electrocuted in the western U.S and Canada where Harness (1997) reported 272 eagle electrocutions between 1986–96. Electrocution accounted for 16% of the Golden Eagle deaths in the Diablo Range, California between 1994–97 (Hunt et al. 1999).

Lead accounted for most poisoning deaths of Golden Eagles. Elevated lead levels (>0.20 ppm) occurred in 36% of 162 eagles sampled in 1985–86 from southern California (Pattee et al. 1990). Elevated levels also occurred in 46% of 281 wintering eagles captured in southeastern Idaho between 1990–97 (Craig and Craig 1998), and 56% of 86 spring migrants in Montana trapped between 1985–93 (Harmata and Restani 1995). Sources of lead have not been documented definitively, but are likely from lead shot or bullets in hunter-killed upland game birds and mammals (Wayland and Bollinger 1999), particularly deer (Pattee et al. 1990) and ground squirrels (Harmata and Restani 1995) with waterfowl as a secondary source. Mortality from ingested shot and bullet fragments occurs occasionally (P. Redig pers. comm.). Blood lead levels of recaptured wintering individuals in Idaho did not decrease over 1–5 yr, suggesting repeated or continual exposure to lead in the environment (Craig and Craig 1998). Four (13%) of 31 dead Golden Eagles examined from 1990–96 from the Canadian Prairie Provinces had been poisoned and three (10%) were sublethally exposed to lead (Wayland and Bollinger 1999). In Idaho, seven of 16 dead Golden Eagles necropsied between 1977–86 were lead poisoned (Craig et al. 1990). Agricultural pesticides, mainly organophosphates and carbamates, accounted for most of the remaining poisoning deaths. In the latter cases, eagles often died by consuming other animals that were poisoned or by consuming baits placed to kill other wildlife.

DISCUSSION

Nesting Golden Eagles. Although data provide conflicting evidence on population trends, available information suggests that nesting populations in Alaska and Canada are stable and, for the most part, doing well. The status of nesting Golden Eagles in the western U.S. is less clear. Although some data, such as the BBS, suggest stable populations throughout the western U.S., some populations have declined. Areas like the Snake River Birds of Prey National Conservation Area may have experienced a decrease in carrying capacity (Steenhof et al. 1997). Shrub loss and declining jackrabbit populations have been associated with small, but steady, declines in the intermountain West; declines in southern California have been attributed to urbanization. Although some nesting populations in the western U.S. have decreased, productivity has not declined, except in one population This agrees with observations of other eagle species where lower quality (or less productive) territories are abandoned in some declining popula-

tions before productivity at higher quality territories declines (Ferrer and Donazar 1996).

Conclusions from Migration Counts. Migration counts in the eastern U.S. suggest a decline in Golden Eagles from the 1930s to the early 1970s, with a stable or increasing trend since the early 1970s. No significant trends were reported for Golden Eagles in the West since the mid-1980s. However, recent increases in adult detection rates and a decrease in migratory immatures have raised concern about conditions for breeding birds and possible lowered reproduction of Golden Eagles in parts of the western U.S. (J. Smith pers. comm.).

Golden Eagle population trends from migration counts should be assessed judiciously because of inconsistencies in data collection among years and count sites, inconsistencies and biases in assessing passage rates, and variability in counts and passage rates caused by weather and eagle behavior (Gould and Lewis 1998, Fuller and Bates 1999). In addition, the origins and destinations of most birds seen at migration count sites are unknown. Significant declines at a migration site could reflect problems throughout the range or merely at an isolated nesting or wintering area. It is difficult to develop management strategies to address possible causes of declines.

Western migration count sites on the continental divide in the Rocky Mountains at or just north of the U.S.-Canadian border (49–51°N latitude) show potential to provide information on trends of Golden Eagle populations from Alaska and western Canada. Large numbers of Golden Eagles pass through these sites, and information from satellite telemetry studies suggests these migration count sites may be on a flight path for Golden Eagles migrating from Alaska and western Canada (Fuller et al. 1995, McIntyre 2000).

Recommendations for Monitoring. Information we present in this paper illustrates the need for more effective monitoring of Golden Eagle populations in North America. We recommend that long-term nesting surveys continue, specifically in Denali National Park (McIntyre 2001), the Snake River Birds of Prey NCA (Steenhof et al. 1997), and San Diego County, California (Bittner and Oakley 1999). Continuous data from these areas provide valuable insights about eagle responses to different environmental problems in diverse geographical areas. We recommend that survey areas be developed for monitoring nesting eagles in Canada, particularly in areas that have been surveyed in the past (see Kirk and Hyslop 1998). Long-term data sets from areas such as north-central Utah (Keller and Smith 1998) should be analyzed and evaluated to determine if these areas should become additional long-term monitoring sites. The area in central Oregon studied by Anderson (1985) also should be resurveyed to ascertain if the population is still depressed or whether it has rebounded. We recommend monitoring the major prey (e.g., black-tailed jackrabbits) concurrently with eagle nesting surveys, specifically in those areas with background prey data; i.e., the Snake River NCA (Steenhof et al. 1997) and Denali National Park (McIntyre and Adams 1999).

We recommend that migration counts continue in the western Rocky Mountains >50°N latitude because they have potential to reflect trends in western Canada and Alaska. Counts at raptor migration count sites should continue to be evaluated (e.g., Gould and Lewis 1998, Fuller and Bates 1999) to determine if they provide meaningful data about status and trend of eagle populations. Information also is needed about the origin and destination of eagles passing through migration count sites.

Counts of Golden Eagles along midwinter Bald Eagle (*Haliaeetus leucocephalus*) survey routes also may provide long-term trend data. More than 300 Golden Eagles have been counted annually on 220 standard routes in 28 states since the mid-1980s (USGS unpubl. data). These January counts occur in Bald Eagle wintering habitat, which may not be prime Golden Eagle habitat. The feasibility of using numbers and age classes of Golden Eagles counted on mid-winter Bald Eagle survey routes for trend analyses should be assessed.

Winter aerial surveys along transects also could provide useful information about population trends, if they are conducted over at least 10 yr to span a complete jackrabbit population cycle. Data from USFWS aerial surveys in six states during the 1970s might provide valuable baseline data on winter eagle densities and age ratios, if the surveys were resumed. These surveys are repeatable because they were conducted on random transects and sampled in a consistent fashion each year. They also are relatively inexpensive to conduct; in southern Idaho, we surveyed 1600 km of transects, using 20 hr of aircraft time. These aerial surveys, like the midwinter Bald Eagle counts, sample populations that contain both the resident and mi-

grant birds. It is extremely difficult to attribute whether change in status is a result of a change in the resident or migrant population or both.

An accurate evaluation of eagle population status requires knowledge about status and trend of floaters (nonterritorial, nonbreeding adults) in a population in addition to the nesting segment of the population (Hunt 1998, Hunt et al. 1999, Bart et al. 1999). Stable populations contain an adequate number of floaters that readily replace breeding adults. Although difficult to obtain, accurate assessment of the floating segment is critical for assessing status of populations. Detecting decreases in the proportion of floaters provides early warning of population declines (Hunt 1998, Bart et al. 1999). Research is needed to develop a feasible means to efficiently gather information on the proportion of floaters in populations.

Fall aerial surveys show potential for assessing changes in resident eagle populations in the western U.S. Surveys conducted in the early fall when young are dispersing from their nesting areas and just prior to arrival of migrants include all segments of the population, including floaters, in the survey area. Like the winter aerial surveys, these fall surveys are repeatable and inexpensive, and they should be conducted for at least 10 yr. Fall surveys have potential for migratory populations if surveys are conducted after young disperse, but before migration.

Another way to monitor Golden Eagle populations is to monitor the threats they face. Because most eagle mortality is human-related, monitoring causes of death including electrocution, collisions, and lead levels should continue.

Standard protocols for inventory and monitoring must be established and followed to effectively assess status and trends of North American Golden Eagle populations. We found it difficult to make adequate assessments because of inconsistencies among sites and years and, even worse, inconsistencies among years within sites. The North American Raptor Monitoring Strategy (Anonymous 1997) may provide the necessary vehicle to address these problems. A goal of this strategy is to develop standard protocols for monitoring various raptor species, including Golden Eagles. Local declines of Golden Eagles and a recent request from Native Americans to harvest this species in the southwestern U.S. have prompted the need for a range-wide inventory and long-term monitoring of Golden Eagle populations in North America. Populations must be monitored consistently throughout the species' range, and well-designed inventory and monitoring protocols are essential to ensure the future long-term stability of the Golden Eagle in North America.

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A CONSERVATION FRAMEWORK FOR THE GOLDEN EAGLE (*AQUILA CHRYSAETOS*) IN SCOTLAND

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ABSTRACT.—The current population of around 420 breeding pairs of Golden Eagles (*Aquila chrysaetos*) in Scotland has been relatively stable for the past two decades. A century ago, both the breeding population and breeding range were probably much less than now, although a century before that the range was much more extensive than it is even today. Current factors constraining the Golden Eagle in Scotland include illegal killing, disturbance at nests, loss of hunting range by conversion of open hills to closed forests, and loss of wild food sources such as grouse and hares as a result of overgrazing of upland vegetation by large herbivores such as sheep and deer. Anticipated future constraints include the development of wind farms and the expansion of native woodlands. Current conservation legislation provides for the establishment of "protected areas" for valued habitats and species, and further legislation makes it an offense to kill Golden Eagles or knowingly to cause disturbance at nest sites. International commitments such as the European Union Wild Birds Directive have placed additional conservation obligations on the government of the United Kingdom that will probably not be met solely by reliance on protected areas and species protection measures. Effective conservation of widely-distributed birds such as the Golden Eagle requires measures to address constraints in the wider environment. In this paper, we subdivide the current and historical range of Golden Eagles into a number of zones founded on the Natural Heritage Zones approach being developed by Scottish Natural Heritage. This zonal approach provides a geographical framework for identifying key constraints on the population and provides an objective basis for the identification of targeted conservation policies.

KEY WORDS: *Golden eagle*; Aquila chrysaetos; *conservation*; *framework*; *constraints*; *zones*.

Un trabajo marco para la conservación del águila real (*Aquila chrysaetos*) en Escocia

RESÚMEN.—La actual población de cerca de 420 parejas reproductivas de águilas reales (*Aquila chrysaetos*) en Escocia, han estado relativamente estables durante las dos décadas pasadas. Un siglo atrás, tanto la población reproductiva como el rango de apareamiento fueron probablemente mucho menores que ahora, aunque un siglo atrás ese rango era mucho mas extensivo de lo que es aun hoy. Los actuales factores que restringen al águila real en Escocia incluyen la caza ilegal, la perturbación de los nidos, la perdida del ámbito de caza por transformación de las colinas abiertas en bosques cerrados, y la perdida de recursos de comida silvestre como los urogallos y las liebres como resultado de sobre pastoreo de la vegetación de la meseta por grandes herbívoros tales como ovejas y venados. Las restricciones proyectadas al futuro incluyen el desarrollo de granjas de energía eólica y la expansión de las arboledas nativas. La legislación actual en cuanto a conservación facilita el establecimiento de "áreas protegidas" para hábitats y especies valiosas, y adicionalmente la legislación castiga como delito el matar águilas reales o causar conscientemente perturbación a los sitios nido. Los comités internacionales tales como la Directiva de la Unión Europea para Aves Silvestres han colocado obligaciones adicionales en cuanto a conservación sobre el gobierno del Reino Unido que probablemente no se responsabilizaría exclusivamente por la seguridad en las áreas protegidas sino también de las medidas de protección para las especies. La conservación efectiva de aves ampliamente distribuidas como el águila real requieren de medidas que dirijan el problema de las restricciones a un medio ambiente mas amplio. En este articulo, subdividimos el rango histórico y el actual de la águilas reales dentro de un numero de áreas encontradas sobre las Zonas de Patrimonio Natural aproximación que esta siendo desarrollada por el Patrimonio Natural Escocés. Este enfoque zonal provee un marco geográfico para identificar las restricciones claves

sobre la población y provee una base objetiva para la identificación de políticas de conservación puntuales.

[Traducción de César Márquez y Victor Vanegas]

Until the middle of the 18th century, the range of the Golden Eagle (*Aquila chrysaetos*) in Britain and Ireland extended beyond its Scottish heartland into northern England as far south as Derbyshire, into the mountains of north Wales, and into much of western Ireland from Donegal to Kerry (Holloway 1996). The 19th and early 20th centuries were periods of intense persecution of birds of prey in Britain, and coincided with a rise in the use of upland areas for sport shooting, especially for Red Grouse (*Lagopus lagopus*). Because they were perceived as competitors with man for game species, and also because predators like eagles were considered threats to domestic stock such as sheep, large numbers of birds of prey were shot, trapped, or poisoned during this time (Brown 1976). This led to substantial range reductions for most raptors and to the ultimate extinction of several species from the native avifauna such as the White-tailed Eagle (*Haliaeetus albicilla*) (see Love 1983).

Today, the Golden Eagle population in Scotland is relatively stable, having undergone a gradual recovery since it was first given full statutory protection under the Protection of Birds Act in 1954 (Watson 1997). Its nadir was probably reached in the decade prior to World War II and the population may then have been as low as 150–200 pairs, entirely confined to the more remote parts of the Highlands and islands of Scotland. The first comprehensive survey of the breeding population in Britain was carried out in 1982 and repeated in 1992. The results of these two surveys were very similar with 424 and 422 territories occupied by pairs of eagles and 87 and 69 territories containing single birds in 1982 and 1992, respectively (Dennis et al. 1984, Green 1996). In both years, only one or two pairs were found in England, and the remainder were in Scotland (Fig. 1).

This paper assesses current constraints on the Golden Eagle population in Scotland and lists the existing measures for the protection and conservation of the bird. It goes on to explore a more strategic approach to the conservation of the species in the light of the international commitments of the government of the United Kingdom for the protection of rare and endangered species, notably the European Union Directive on the Conservation of Wild Birds (79/409/EEC) (see Tucker and Heath 1994 for details).

CURRENT CONSTRAINTS

Contemporary constraints fall into two broad categories: those that have direct and immediate effects such as persecution and disturbance at nesting sites, and those that operate indirectly and more subtly such as changes in land use and management.

Persecution and Disturbance. Even after 45 yr of statutory protection, many Golden Eagles are still killed illegally each year in Britain and the commonest method of deliberate persecution is poisoning, although shooting and trapping still occur (Watson 1997). During the period 1979–89, a minimum of 13 Golden Eagles were shot or trapped and an additional 27 individuals were killed by poisoning (RSPB and NCC 1991). Because Golden Eagles readily feed on carrion, they are especially vulnerable to carcasses laced with poison. These baits, the use of which is illegal in Britain, are usually laid in places that are visited by predatory and scavenging birds or mammals. While the principal target is usually the red fox (*Vulpes vulpes*), poisoned baits are indiscriminate and annually account for many deaths of birds of prey including Common Buzzards (*Buteo buteo*), Red Kites (*Milvus milvus*), and Golden Eagles.

Within the range of the Golden Eagle in Scotland, the use of poisoned baits is most frequent along the eastern and southern fringe of the Highlands and in the Southern Uplands, typically in areas that are managed for Red Grouse. In these localities, poisoning is a major factor inhibiting the establishment of breeding territories, reducing breeding success, and preventing expansion of the breeding population. Where poisoning is endemic, adult birds are typically absent and ranges are consistently vacant or occupied only periodically by subadults that rarely survive long enough to breed. In the worst-affected areas, these poisoning black spots act as critical mortality sinks for Golden Eagles.

During the breeding season, Golden Eagles are vulnerable to the effects of both deliberate and un-

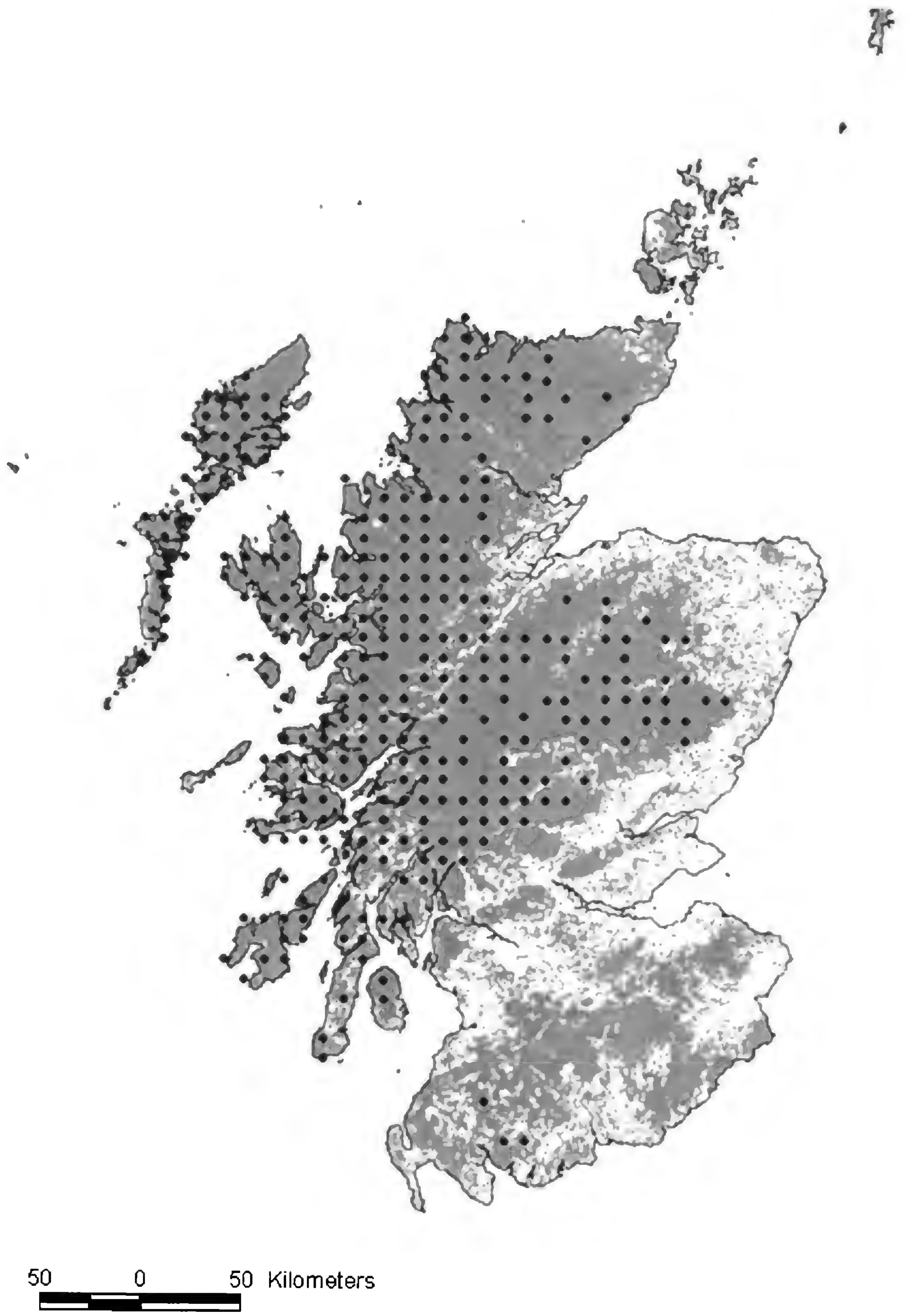

Figure 1. The distribution of the Golden Eagle in Scotland based on breeding attempts in 10 × 10 km squares in 1992. For reasons of confidentiality, records for four 10 × 10 km squares have been omitted.

intentional disturbance at nesting sites. The main consequence of disturbance is to reduce overall breeding performance. Watson and Dennis (1992) assessed the impact of deliberate disturbance on over 300 breeding attempts monitored during the 1982 national survey of Golden Eagles. They concluded that overall production of young may have been reduced by around 18% as a result of deliberate disturbance. As in the case of killing of adult eagles, the incidence of deliberate disturbance was most prevalent around the eastern fringe of the current Golden Eagle range.

Land Use and Management. The principal land uses in upland Scotland where Golden Eagles live are largely extensive and are either managed for grazing of both domestic animals and wild game

species or for forestry (MLURI 1993). In general, land use changes tend to occur relatively slowly and consequently any effects on eagle populations can be difficult to measure, with precise causal links hard to identify. Over the past 50 yr, the main changes in and influences of land use in the Scottish uplands have been large-scale increases in plantation forestry, continued high densities or increases in sheep grazing, and marked increases in the numbers of red deer (*Cervus elaphus*) raised on the remaining open ground. There have been long-term declines in many areas in the numbers of several medium-sized wild herbivores such as Red Grouse and mountain hares (*Lepus timidus*), especially in the west of the eagle range in Scotland. These declines are mainly attributable to the effects of overgrazing by sheep and deer, leading to loss of dwarf shrubs such as heather (*Calluna vulgaris*) on which grouse and hares depend for food and cover, and their replacement by ecologically impoverished grass-dominated vegetation.

Since 1945, huge tracts of open landscapes in the uplands of Britain have been converted to plantation forestry. Within the Golden Eagle range, the greatest extent of plantation forestry has occurred in southwest Scotland and in Argyll in the southwest Highlands. Until quite recently, most forestry in the uplands was with exotic conifers such as Sitka spruce (*Picea sitchensis*) and lodgepole pine (*Pinus contorta*). After about 10 yr, the canopy closes in these plantation forests and they become densely-packed stands of fast growing trees with very little structural or species diversity. For the Golden Eagle, this type of afforestation can lead very quickly to the loss of food in the form of sheep and deer carrion and, in due course, to the removal of virtually all hunting potential once the tree canopy closes (McGrady et al. 1997).

Two studies, one in southwest Scotland and another in Argyll, have demonstrated reduced breeding success by eagles linked to increases in afforestation (Marquiss et al. 1985, Watson 1992). The effects of afforestation on breeding density take longer to show, although there is evidence that, in one of the most heavily afforested landscapes in south Argyll, there has been a loss of 60% of the breeding eagles over the past 30 yr (Watson 1997).

The relationship between Golden Eagles in Scotland and large grazing animals, notably ungulates such as sheep and deer, is complex. On the one hand, eagles depend on carrion in the form of dead sheep and deer, especially for food in winter. Watson et al. (1992) showed that variation in breeding density of eagles across Scotland could be explained largely by differences in the amount of carrion available. Highest densities of eagles occurred in the west mainland and on the islands where amounts of deer and sheep carrion were greatest. However, the same study showed no such positive correlation between carrion availability and breeding performance. Instead, breeding success was positively correlated with the numbers of medium-sized wild herbivores such as Red Grouse, Rock Ptarmigan (*Lagopus mutus*), mountain hare, and rabbit (*Oryctolagus cuniculus*). So, in places where eagles were not subjected to human persecution, breeding success was highest (around 0.8 young/pair) in the eastern Highlands where grouse and hares were most numerous. On the islands off the west coast where rabbits are especially plentiful, eagles produce around 0.6 young/pair. Breeding success was typically close to the national average of about 0.5 young/pair in a wide band from the southwest Highlands through the central Highlands to the northwest Highlands. In this zone, there were low to moderate numbers of grouse, ptarmigan, and hares reflecting some overgrazing by red deer, with consequent heather loss. Finally, the poorest eagle breeding performance (around 0.3 young/pair) was in the west-central Highlands where grouse and hare numbers were exceptionally low and where there were very few rabbits as alternative prey. In this region, overgrazing by large numbers of red deer and both past and present high sheep numbers, combined with a very wet climate, have resulted in loss of much of the "natural" heather cover, which in turn explains the low grouse and hare numbers.

In conclusion, abundant winter carrion, which occurs where large ungulates are present in high numbers, can lead to exceptional densities of eagles. However, excessive grazing pressure by large ungulates, notably in the wet west of Scotland, can also lead to the serious loss of medium-sized wild herbivores that are critical summer food for eagles if they are to breed successfully.

FUTURE CONSTRAINTS

Within the range of the Golden Eagle in Scotland, there are a number of changes that could be anticipated over the next decade or two. One is the likely increase in the number of wind farms which are being promoted in order to increase the proportion of energy generation from renewable

sources, and for which the windy west of Scotland offers considerable potential. Another is the anticipated recovery of the White-tailed Eagle population following the successful reintroduction of that species into its previous range on the islands and adjacent mainland of western Scotland (Love 1988). A third, and rather different type of potential constraint, is the change in current forestry practices in upland Scotland. This is now favoring the reestablishment or restoration of woodlands of native species and more natural structure, as opposed to the exotic conifer plantations of the past. Bearing in mind the wider biodiversity benefits from the recovery of Scotland's much depleted native woodland resource, to what extent does this pose a threat to Golden Eagles? Fourthly, there is the steady increase in recreational use of the uplands by the general public and the prospect that this could lead to increased casual disturbance of eagles during the breeding season.

CURRENT CONSERVATION MEASURES

An effective conservation strategy for rare but widely-distributed species such as the Golden Eagle needs to include three elements: species protection, site protection, and conservation of the wider environment.

Species Protection. The Golden Eagle in Britain is listed on Schedule 1 of the Wildlife and Countryside Act (1981). This protection includes special penalties for the killing and intentional disturbance of Golden Eagles during the nesting season. Although all forms of killing and intentional disturbance are illegal under this act, there continues to be substantial disregard for the law. In part, this is because of the comparative difficulty of bringing prosecutions where the burden of proof is high, but also because the deterrent effect of the financial penalties available in the event of a successful prosecution is low.

Site Protection. The current focus on site protection for Golden Eagles in Scotland is a result of the commitment of the government of the United Kingdom to implement the European Union Wild Birds Directive. The Golden Eagle is listed in Annex 1 of the Directive, which requires that species listed in Annex 1 "shall be the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in the area of their distribution" and that "member states (of the European Union) shall classify in particular the most suitable territories in number and size as special protection areas (SPAs) for the conservation of these species, taking into account their protection requirements in the geographical sea and land area where this directive applies." At the present time, there are five classified and three more proposed SPAs for Golden Eagles in Scotland (Fig. 2), and these contain just over 12% of the Golden Eagle population in the United Kingdom.

Conservation in the Wider Environment. While the level of protection afforded Golden Eagles within these SPAs is high, and should certainly ensure the continued survival of the species in these localities, site protection can only be a contribution to the long-term conservation of such a widely-distributed species. We believe the challenge for conservationists in Scotland is to design a strategic approach to the protection of birds such as Golden Eagles in the wider environment. Such an approach must necessarily compliment existing species and site protection measures. In the following section, we propose a framework for the conservation of Golden Eagles in Scotland that goes substantially beyond the existing site and species conservation arrangements.

A CONSERVATION FRAMEWORK

We propose the following as an overall aim for the effective long-term conservation of Golden Eagles in Scotland: maintenance of the present favorable condition of the population by implementing effective site and species protection measures and adoption and implementation of conservation policies that are targeted at known constraints across the species current range.

Favorable Condition. There are a number of key elements in this goal. First, it requires an agreed definition of what is meant by "favorable condition." We propose that the concept of favorable condition in the case of the Golden Eagle should take into account population size overall, average breeding performance, and the extent of the known historical range that is occupied. We propose that, on the first of these criteria, the Golden Eagle population in Scotland could be judged to be in favorable condition if the number of territories occupied by pairs is maintained at not less than 450–500. On the basis of this target, the current population is not in favorable condition (Table 1). We argue this assessment on the grounds that some 60–80 eagle ranges are currently occupied by single birds, and because the distribution of single occupancy coincides closely with areas of

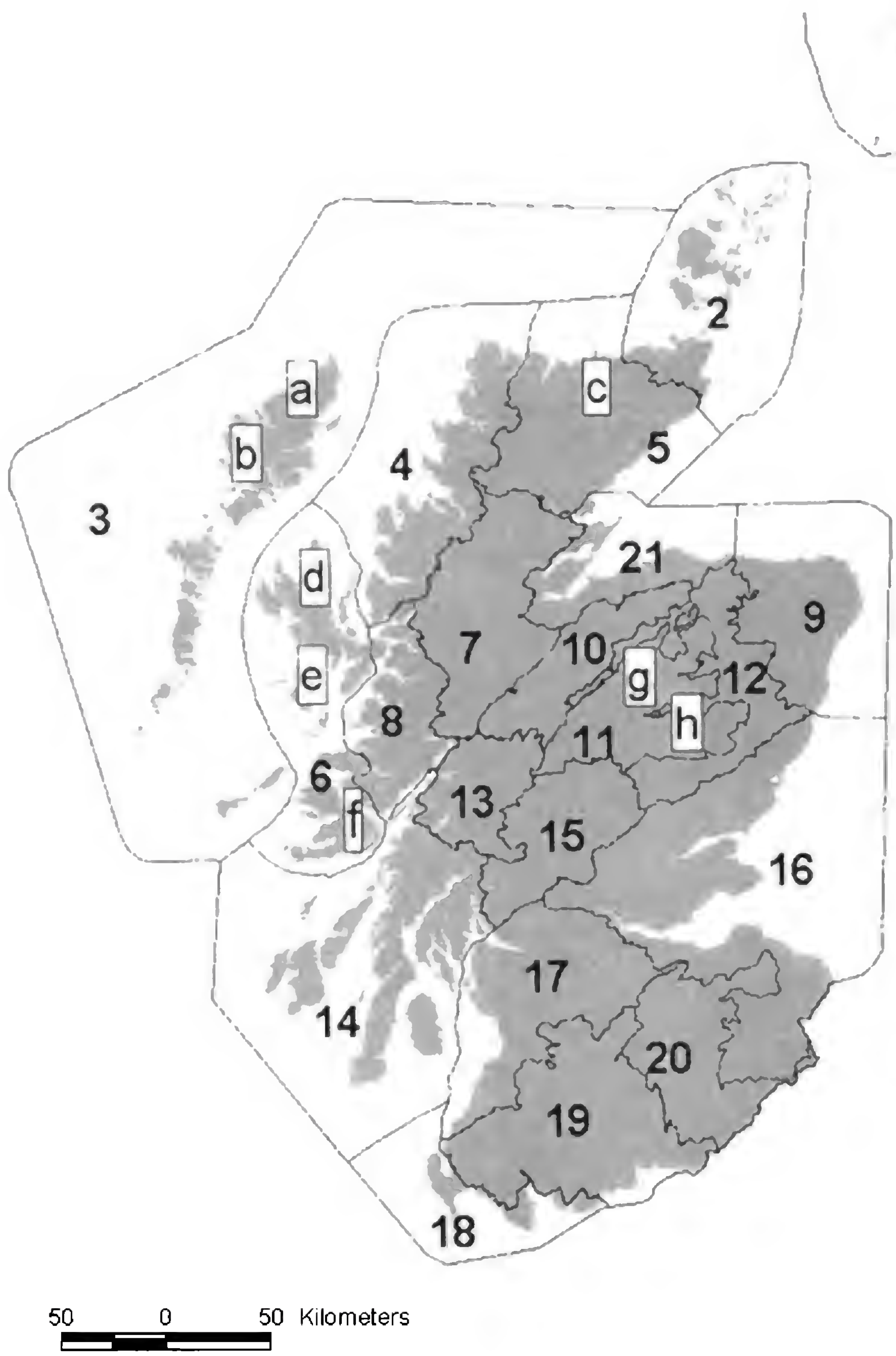

Figure 2. Map of Scotland showing the boundaries of SNH Natural Heritage Zones (2–21, excluding Shetland Zone 1) and the location of proposed and classified Special Protection Areas for the Golden Eagle (a–h: a = Lewis Peatlands, b = North Harris Mountains, c = The Peatlands of Caithness and Sutherland, d = Skye Mountains, e = Rum, f = Mull hills and coast, g = The Cairngorms, and h = Caenlochan).

human persecution (Dennis et al. 1984, Watson 1997).

Identifying a condition target based on breeding performance is more difficult because of substantial between-year and area variation. Nevertheless, we recommend that condition should be judged to be favorable if the breeding success of the population overall remains >0.5 young/territorial pair/yr on average over a 5-yr period, and if no substantial part of the population in a particular geographical area is producing on average <0.4 young/territorial pair/yr over a 5-yr period. The first target is currently met (Watson unpubl. data), but the second is not, notably in a substantial area of the

Table 1. Summary of Golden Eagle range occupation, breeding numbers, breeding performance and constraints on favorable condition according to 14 Natural Heritage Zones in Scotland.

NATURAL HERITAGE ZONE[a]	EAGLE OCCUPATION OF SUITABLE HABITAT[b]	EAGLE BREEDING NUMBERS[c]	EAGLE BREEDING PERFORMANCE[d]	CONSTRAINTS
3	82% (44)	51	3?	sheep > persecution
4	69% (39)	37	4	deer > persecution
5	28% (53)	16	3?	persecution > nest site availability
6	100% (43)	70	5	sheep > commercial forestry
7	77% (52)	58	5	deer > persecution
8	80% (30)	40	3	deer > sheep
10	54% (28)	15	6	persecution > deer
11	59% (44)	28	7	persecution > deer
12	50% (16)	9	6?	persecution > commercial forestry > sheep
13	71% (24)	30	2	deer > sheep
14	85% (46)	43	5	commercial forestry > sheep > persecution
15	69% (32)	20	5?	persecution > sheep > deer > commercial forestry
19	10% (30)	3	2	commercial forestry > persecution > sheep
20	0% (31)	0	0	persecution > sheep > nest site availability

[a] See Fig. 2.

[b] % of 10 × 10 km Ordnance Survey grid squares with >50% upland habitat (Land Cover of Scotland 1988, upland summary classes MLURI 1993) containing breeding Golden Eagle home range centers (*sensu* McGrady et al. 1997) in 1992. Number of upland grid squares in brackets.

[c] Number of breeding pairs in 1992.

[d] Set relative to 1985 standard due to data availability and it being an apparently average year (Watson 1997) (young/pair/year). 0 = 0–0.09, 1 = 0.10–0.19, 2 = 0.20–0.29, 3 = 0.30–0.39, 4 = 0.40–0.49, 5 = 0.50–0.59, 6 = 0.60–0.69, 7 = 0.70–0.79.

west-central Highlands of mainland Scotland (Table 1, Watson 1997).

At present, approximately 72% of the apparently suitable range of Golden Eagles in Scotland is occupied by breeding birds (Table 1), and the figure for the United Kingdom as a whole may be as low as 60% (Newton 1994). For the range criterion, we recommend that the population should be judged to be in favorable condition when substantially all the apparently suitable habitat is occupied. We accept that this criterion must allow for continued nonoccupancy of some of the historical range. This could arise as a result of substantially natural causes (e.g., the recovery of the White-tailed Eagle population and any associated Golden Eagle range reduction), or where long-term and irreversible habitat change has occurred as a result of human or natural causes. Taking these considerations into account, we believe this condition target is probably not met in several parts of the eastern Highlands and in the Southern Uplands at the present time.

Site and Species Protection. This goal also recognizes the role of "site and species protection measures" and, by use of the word "effective," it acknowledges that these measures may require testing and review from time to time. We believe that, in respect of species protection, the current legislation in Britain probably needs to be amended further to deter people who kill and intentionally disturb eagles and other specially protected species. The distribution of classified and proposed SPAs is shown in Fig. 2. Given the inevitable limitations of a site-based approach in addressing the overall conservation of the species, we do not believe there is a strong case for an appreciable increase in the number or extent of these SPAs.

Constraints and Conservation in the Wider Environment. A third important element of the goal is the requirement for conservation policies targeted at constraints affecting eagles in the wider environment across the range. In this context, "conservation policies" should be taken to include the agreed set of advice, prescription, and incentive to be followed during the process of decision-making by government and its agents. We propose that such policies are generally amenable to targeting on a geographical basis across Scotland, giv-

ing the opportunity to adjust the priority attached to a range of prescriptions or incentives, dependent on the anticipated effect on the overall goal of achieving or maintaining favorable condition for the Golden Eagle population.

We propose that one starting point for the development of a targeted, and therefore prioritized, policy framework is to use the Natural Heritage Zones approach developed by Scottish Natural Heritage (SNH 1998, Fig. 2, Table 1). The SNH zonal program has identified 21 Natural Heritage Zones that reflect the variation in biological and landscape qualities across Scotland. The bulk of the Golden Eagle population is found within 13 of these zones and, in one other (Zone 20), Golden Eagles were present historically and could occur again in the future.

Table 1 lists the 14 zones, the number of breeding territories currently occupied by Golden Eagles in each zone, an assessment of range occupancy, and an estimate of current average breeding performance. It also lists the main constraints that presently affect Golden Eagle populations within each of the zones. At the present time, this list of constraints should be viewed as indicative, although it is substantially supported by the analysis of threats to Golden Eagles in Scotland given in Watson (1997). We are currently working on quantitative assessments of these constraints, to be published in due course. We do not expect that our analysis will alter appreciably the allocation of constraints to the particular zones. The principal finding of the analysis so far is to affirm that human persecution on eagle populations is a key issue in the east of the range (zones 5, 10, 11, 12, and 20), the influence of high deer numbers is a key factor in the north and west of the range in mainland Scotland (zones 4, 7, 8, and 13) and possibly also in the parts of the east (zones 10, 11, and 15), the influence of commercial forestry is greatest in the southwest (zones 14 and 19) and may also be an issue in parts of the southeast Highlands (zones 12 and 15), and high sheep numbers are a key factor on the islands (zones 3 and 6) in the southwest Highlands (zones 8, 13, 14, and 15), and in the Southern Uplands (zones 19 and 20). The only other constraint that we have identified and which we believe may now be having an appreciable effect on eagles is the availability of nest sites (zones 5 and 20). In these two zones, there is a comparative lack of suitable cliff nesting sites and there are few large trees such as Scotch pine (*Pinus sylvestris*) which would offer alternative nesting places.

Our analysis is also investigating the geographical distribution of constraints linked to the probable future expansion of wind-farms, expansion of the reintroduced White-tailed Eagle population, increases in the extent of native woodland in the uplands, and the possible effects of increased recreational use of the uplands by people. Although work here is at an early stage, our initial view is that the zonal approach offers a useful way of anticipating and responding constructively to new constraints while taking into account existing constraints and their combined influence on the overall goal of achieving favorable condition for the population as a whole.

CONCLUSION

We propose a strategic framework for the conservation of Golden Eagles in Scotland, founded on site and species protection measures complimented by the use of targeted conservation policies designed to address key constraints on Golden Eagles in different parts of the species current range. Geographical targeting of conservation policies is possible thanks to relatively good biological information on eagle numbers, range and breeding success, good understanding of current constraints affecting eagle populations, and the existence of a geographical or zonal framework that is able to accommodate information on eagle "condition" and land use "constraints."

We believe this strategic approach has merit and commend, in particular, the proposed approach to the conservation of Golden Eagles in the wider countryside. This combines simplicity with robustness. Being relatively straightforward, it has the prospect of being adopted by decision makers. Its robustness is founded on the ability of the strategy to accommodate adjustments to policies or policy priorities in the light of new information on eagle "condition" or new types of land use "constraint."

The next step in the development of the overall strategy will be to articulate policy objectives designed to address the range of constraints, tackling in the first instance issues relating to persecution, deer management, sheep, and forestry. There is the opportunity to address current land management practices that are contributing to lack of favorable condition in the eagle population. We are also exploring the possibility of making predictions on the effects of proposed policy changes on the

various measures of condition, and thereby providing a useful test of the effectiveness of these policies. In addition, we propose to test the usefulness of the framework in helping identify conservation policies and priorities for Golden Eagles in relation to new but readily anticipated constraints such as the development of wind farms and the current expansion of new native woodlands in the uplands.

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PATTERNS IN NESTING AREA OCCUPANCY AND REPRODUCTIVE SUCCESS OF GOLDEN EAGLES (*AQUILA CHRYSAETOS*) IN DENALI NATIONAL PARK AND PRESERVE, ALASKA, 1988–99

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Abstract.—Annual territory occupancy and reproductive success of nesting Golden Eagles (*Aquila chrysaetos*) were monitored at 58–76 nesting areas in Denali National Park and Preserve, Alaska since 1988. Data were collected annually using two standardized aerial surveys and follow-up foot surveys. Aerial surveys were conducted during the early incubation period (late April) to determine occupancy and nesting activities and late in the nestling period (late July) to count fledglings and determine nesting success. All aerial surveys were conducted using a Bell 206B Jet Ranger helicopter with one or two experienced observers and an experienced wildlife pilot. Aerial surveys were the most time- and cost-efficient means to survey the 1800-km^2 study area. Average flight time during late April surveys was 12.8 flight hr (over 3 d) and during late July was 5.3 flight hr on 1 d. Duration of surveys depended on nesting activities. Foot surveys were useful for making longer observations in areas where territory occupancy could not be determined during aerial surveys. Annual occupancy rates averaged 83%. Laying rates, success rates, and overall population productivity varied significantly over the study period. Fledgling production varied greatly over the 12-yr period from a low of 9 fledglings in 1994 to a high of 70 fledglings in 1999. Laying rates, mean brood size, and overall population productivity were significantly correlated with abundance of cyclic snowshoe hare (*Lepus americanus*) and Willow Ptarmigan (*Lagopus lagopus*) populations. Cyclic prey did not influence occupancy rates. Most territories were occupied more than 8 yr, but four remained vacant throughout the study. Productivity varied greatly among nesting territories. More than 50% of all fledglings were produced at 17 nesting areas and >75% of all fledglings were produced at 35 nesting areas.

Key Words: *Golden Eagle;* Aquila chrysaetos; *reproduction; Denali National Park; Alaska.*

Patrones en la ocupación del area de anidamiento y el éxito reproductivo de las águilas reales (*Aquila chrysaetos*) en el parque nacional y coto de caza de Denali, Alaska, 1988–99

Resúmen.—La ocupación anual del territorio y el éxito reproductivo de águilas reales (*Aquila chrysaetos*) durante la anidación fueron monitoreados en 58–76 áreas de anidación en el parque nacional y coto de caza de Denali, Alaska desde 1988. Los datos fueron colectados anualmente usando dos estudios aéreos estandarizados y prosiguiendo con estudios a pie. Los estudios aéreos fueron desarrollados durante el periodo temprano de incubación (a finales de abril) para determinar la ocupación y las actividades de anidamiento, y durante el periodo tardío de anidación (a finales de Julio) para contar los polluelos y determinar el éxito reproductivo. Todos los estudios aéreos fueron hechos usando un helicóptero Bell 206B Jet Ranger con uno o dos observadores experimentados y un piloto experimentado en vida silvestre. Los estudios aéreos fueron los medios tiempo-costo mas eficientes para estudiar los 1800-km^2 del área de estudio. El tiempo promedio de vuelo durante los estudios de finales de abril fue 12.8 vuelos hora (cerca de 3 días) a finales de julio fue 5.3 vuelos hora cerca de 1 día. La duración de los estudios dependió de las actividades de anidación. Los estudios a pie fueron útiles para hacer observaciones mas largas en áreas donde la ocupación del terreno no pudo ser determinada durante los estudios aéreos. Las tasas de ocupación anual promedian 83% y no varían significativamente en el tiempo. Las tasas de postura, las de éxito y la productividad total de la población variaron significativamente durante el periodo de estudio. La producción de polluelos varió grandemente durante el periodo de 12 años desde un nivel bajo de 9 polluelos en 1994 hasta uno alto de 70 polluelos en 1999. Las tazas de postura, la media del tamaño de la nidada, y la productividad de toda la población estuvieron correlacionadas significativamente con la abundancia de las poblaciones cíclicas de liebres "zapatos de nieve" (*Lepus americanus*) y del urogallo de sauce (*Lagopus lagopus*). Las presas cíclicas no influenciaron las tasas de ocupación. La mayoría de territorios fueron ocupados por mas de 8 años,

pero 4 permanecieron vacantes a través de todo el estudio. La productividad varió grandemente entre los territorios de anidamiento. Mas del 50% de todos los polluelos se produjeron en 17 áreas de anidación y >75% de todos los polluelos fueron producidos en 35 áreas de anidación.

[Traducción de César Márquez y Victor Vanegas]

Few long-term studies have examined the reproductive characteristics of Golden Eagles (*Aquila chrysaetos*) at high latitudes in North America (McIntyre and Adams 1999). Breeding populations in northern North American are migratory, spending ≥5 mo migrating to, wintering in, and returning from temperate latitudes thousands of kilometers from their nesting areas (Gabrielson and Lincoln 1959, Palmer 1988, Brodeur et al. 1996). Many breeding populations depend on cyclic prey and have few alternate prey sources early in the nesting season. This life history strategy is common among birds breeding at northern latitudes and entails high energy demands for migration immediately before annual reproductive efforts. Furthermore, Golden Eagles arrive at their northern breeding areas in late winter when abundance and diversity of their prey is at its lowest annual level.

Golden Eagle reproduction is tied to the abundance of its principal prey (Tjernberg 1983, Bates and Moretti 1994, Steenhof et al. 1997). Snowshoe hare (*Lepus americanus*) and Willow Ptarmigan (*Lagopus lagopus*) are common food sources available to breeding Golden Eagles in interior Alaska early in the nesting season (McIntyre unpubl. data). Hare and ptarmigan experience large amplitude population cycles in Alaska (Buckley 1954, Weeden 1959). From May–August, breeding Golden Eagles in interior Alaska prey heavily upon arctic ground squirrel (*Spermophilus parryii*), as well as hoary marmot (*Marmota caligata*), snowshoe hare, and Willow Ptarmigan (Murie 1944, McIntyre and Adams 1999). Ground squirrels and marmots are obligate hibernators and do not emerge from hibernation until mid-April and early May, long after most eagles have completed their clutches.

In this paper, I describe the reproductive characteristics and evaluate relationships between reproductive components and abundance of cyclic prey of a northern, migratory Golden Eagle population that nests in Denali National Park, Alaska. I also report on patterns of nesting area occupancy and productivity.

METHODS

Study Area. The 1800-km^2 study area, centered at 63°35'N and 149°30'W is in Denali National Park on the north side of the Alaska Range in interior Alaska (Denali). Most of the study area is within a federally designated Wilderness Area and an internationally recognized World Biosphere Reserve. Human activities occur primarily in summer and are concentrated along a gravel road that traverses the study area.

Mountains, broad glacial river valleys, low rolling tundra, and upland areas dominate the study area landscape. Elevations in the study area range from 350–2500 m Most of the study area is above treeline (800 m). Mountains south of the study area exceed 2500 m in elevation and are permanently covered with ice and snow. Sheldon (1930), Dixon (1938), and Murie (1944, 1963) provide detailed descriptions of the vegetation and geology of the study area.

The region has a subarctic montane climate with temperatures ranging from −47°C–32°C. Average annual precipitation is 38 cm, including about 200 cm of snowfall. During 1988–99, snow cover persisted at lower elevations from mid-September through mid-May, an average of 210 d (National Park Service unpubl. data).

Breeding pairs of Golden Eagles return to Denali during late February to early April (Murie 1944, McIntyre 1995). Most clutches are completed by mid-April and nestlings usually fledge in late July and early August (McIntyre 1995). Autumn migration starts in late September and continues into October.

Terminology. I followed terminology recommended by Postupalsky (1983), Newton and Marquiss (1982), and Steenhof (1987) to describe occupancy and activities at nesting areas. An area where at least one nest was found and where no more than one pair of Golden Eagles nested in one year was considered a nesting area. Nests were assigned to unique nesting areas based on their history of use and location. A nesting area was considered occupied if a territorial pair or evidence of a territorial pair (such as an incubating bird, nest construction, or nest maintenance) was observed; otherwise the area was deemed unoccupied.

A territorial pair of Golden Eagles that laid eggs was termed a laying pair (Steenhof et al. 1997). I did not flush birds off nests to count eggs and presumed that incubating birds had eggs. Nestlings that reached 51 days-of-age (or 80% of the mean age at first flight) were considered fledglings (Steenhof 1987). Laying pairs that produced ≥1 fledgling were considered successful pairs

Surveys. I surveyed the study area twice annually by helicopter to find territorial and laying pairs of Golden Eagles and to count fledglings. Additional observations were conducted by dogsled in March and on foot throughout the nesting season to supplement aerial surveys. Another experienced observer usually assisted me with each survey.

During the first aerial surveys each year, we checked all known nests within each nesting area to determine occupancy and describe nesting activities. We also searched for new nests and nesting areas. These surveys

were conducted on two to five consecutive days in late April and early May. Most clutches were completed at this time and hatching had not yet occurred. Nesting areas not classified as occupied during this survey were revisited later in the nesting season to confirm their status. The second annual surveys were conducted in late July or early August to count fledglings and document nesting success. By this time of year, most nestlings were >51-days-old, but few had fledged.

All surveys were flown at 30–40 km/hr and we periodically hovered to observe nest contents. A minimum distance of >100 m was maintained between the helicopter and nest structures during all aerial surveys. We landed and made observations from vantage points on the ground when we could not determine occupancy or nesting activities from the helicopter. We used binoculars (10 × 40) during all aerial surveys, and binoculars and spotting scopes (15–45×) during ground observations. I followed recommendations made by Fyfe and Olendorff (1976) to avoid disturbing adults and nestlings during field activities.

I report annual reproductive performance of Golden Eagles in Denali using four components: (1) occupancy rate, as the proportion of nesting areas surveyed that were occupied by territorial pairs; (2) laying rate, as the proportion of territorial pairs that laid eggs; (3) success rate, as the proportion of laying pairs that produced ≥1 fledgling; and (4) mean brood size, as the average brood size for successful pairs. Population productivity is reported as the mean number of fledglings produced annually per territorial pair.

Index of Prey Abundance. I developed indices of population change of snowshoe hare and Willow Ptarmigan on a broad scale by recording the number of each species observed annually during routine field activities. Annual indices of abundance for snowshoe hare and Willow Ptarmigan were highly correlated in our study ($R^2 = 0.95$, $N = 12$ yr, $P < 0.0001$). Therefore, I used mean number of snowshoe hares observed per field day as our index of spring prey abundance. Results and conclusions were identical when Willow Ptarmigan or combinations of these prey species were used in the analyses.

Statistical Analyses. I used chi-square analyses to test for differences in occupancy rate, laying rate, and success rate among years. Analysis of variance (ANOVA) was used to test for differences in mean brood size among years. I used Pearson's correlation to test for a relationship between Golden Eagle reproduction and spring prey abundance. All statistical tests were run using Statistix® software (Analytical Software 1992). All tests are considered significant at the 0.05 level.

RESULTS

I monitored 56–76 nesting areas annually (Table 1), and the same 62 nesting areas for ≥10 yr. Although I attempted to survey all known nesting areas each year, weather conditions during aerial survey in several years prevented me from making observations at all nesting areas.

Overall, occupancy rate averaged 83% and varied significantly among years ($\chi^2_{11} = 22.72$, $P = 0.02$). Of the 62 nesting areas monitored for ≥10 yr, 49 (79%) were occupied ≥10 years and 38 were occupied for 12 consecutive yr. Laying rate was the most variable reproductive component we measured ($\chi^2_{11} = 82.01$, $P < 0.001$), ranging from 33% in 1994 to 90% in 1989. Success rate also varied slightly ($\chi^2_{11} = 19.97$, $P = 0.05$) from a low of 42% in 1994 to a high of 88% in 1996. Annual mean brood size averaged 1.45 fledglings per successful pair and varied significantly among years ($F_{11,291} = 1.98$, $P < 0.05$). Population productivity ranged from 0.16–1.16 fledglings per territorial pair. A total of 455 fledglings were produced during the 12-yr period; 406 fledglings were produced at 62 nests monitored for ≥10 yr. A total of 17 (27%) of 62 nests monitored for ≥10 yr produced 50% of all fledglings from 1988–99. The most productive nesting area produced 15 fledglings over 12 yr, with 8 successful nesting attempts and a mean brood size higher than the population mean (1.88 compared to 1.45).

Annual indices of abundance for snowshoe hare and Willow Ptarmigan were highly correlated during the study period ($R^2 = 0.95$, $N = 12$ yr, $P < 0.001$). The number of hares observed per day annually ranged from 0.7–8.12. The number of ptarmigan observed per day annually ranged from 3–22. Abundance of both species was lowest in 1994.

Occupancy rate and success rate did not change in relation to spring prey abundance (occupancy: $R^2 = 0.04$, $P = 0.89$; success: $R^2 = 0.35$, $P = 0.25$). Laying rate and mean brood size were affected by the abundance of cyclic prey (laying rate: $R^2 = 0.83$, $P = 0.009$; mean brood size: $R^2 = 0.71$, $P = 0.0091$). Because of the significant positive relationships for both laying rate and mean brood size, population productivity also was affected significantly by prey abundance ($R^2 = 0.81$, $P = 0.001$).

DISCUSSION

My results suggest that reproductive success of migratory Golden Eagles in interior Alaska is influenced by fluctuating numbers of prey available to eagles early in the nesting season. I could explain 83% of the variation in Golden Eagle productivity with changes noted in the abundance of spring prey.

Laying rate was the most important factor influencing population productivity of Golden Eagles in Denali during this study. Laying rate varied widely compared to other components of reproduction and was most closely related to spring prey abun-

Table 1. Summary of reproductive characteristics of Golden Eagles (*Aquila chrysaetos*) in Denali National Park, Alaska, 1988–99.

Year	Nesting Areas Surveyed	Nesting Areas Occupied	Pairs With Eggs	Pairs with Fledglings	Total Fledglings	Occupancy Rate (%)	Laying Rate (%)	Success Rate (%)	Fledglings per Occupied Territory	Mean Brood Size
1988	56	47	37	28	38	83.93	78.72	75.68	0.81	1.36
1989	66	50	45	35	58	75.76	90.00	77.78	1.16	1.66
1990	66	46	38	28	47	69.70	82.61	73.68	1.02	1.68
1991	66	51	35	29	43	77.27	68.63	82.86	0.84	1.48
1992	70	57	36	19	26	81.43	63.16	52.78	0.46	1.37
1993	68	55	25	17	23	80.88	45.45	68.00	0.42	1.35
1994	68	58	19	8	9	85.29	32.76	42.11	0.16	1.13
1995	68	59	27	19	25	86.76	45.76	70.37	0.42	1.32
1996	72	62	26	23	30	86.11	41.94	88.46	0.48	1.30
1997	72	63	45	33	54	87.50	71.43	73.33	0.86	1.64
1998	70	62	34	21	31	88.57	54.84	61.76	0.50	1.48
1999	76	71	55	43	71	93.42	77.46	78.18	1.00	1.65

dance. Laying rates were lowest when the spring prey populations were at their lowest level.

Overall, success of laying pairs in Denali was not influenced by spring prey abundance. Before and during laying, snowshoe hare and Willow Ptarmigan constitute most of the available prey for Golden Eagles in Denali (McIntyre and Adams 1999). The importance of these species in the diet of eagles in Denali, however, probably decreases as arctic ground squirrels and hoary marmots emerge from hibernation. However, success rate of eagles in Denali was lowest in years when hare and ptarmigan were at the lowest level of their population cycles. Additionally, mean brood size declined significantly only in years when cyclic prey were scarce. At Kluane Lake, Canada, densities of arctic ground squirrels are strongly correlated with hare abundance (Boutin et al. 1995). If this situation exists in Denali and other areas in Alaska, I expect low success rates and smaller broods of eagles during population lows of hares.

Golden Eagles show great dietary plasticity (Watson 1997). However, the lack of alternate prey may limit diet diversity of Golden Eagles during the early nesting season in northern areas. Few alternate prey are available for Golden Eagles in March and early April in interior Alaska. In Denali, carrion is scarce and carcasses of ungulates are quickly scavenged by terrestrial carnivores (Adams unpubl. data). Throughout interior Alaska, where few alternate prey occur, I expect productivity of Golden Eagles to fluctuate in synchrony with cyclic hare populations. Few empirical data, beyond our study, are available to test this hypothesis. However, Golden Eagles nesting along the Porcupine River in interior Alaska were more successful in years when snowshoe hare were abundant (Ritchie and Curatolo 1982). Similarly, Golden Eagles in southwestern Alaska reared young only in the years when hare densities were high (Petersen et al. 1991).

Occupancy rates of eagles in Denali remained relatively stable over the study period and did not change in relation to abundance of cyclic prey. Most (75%) nesting areas monitored for ≥10 yr were occupied in all years. Golden Eagles are long-lived and it may be advantageous for them to protect nesting areas for future breeding attempts, even when prey conditions are unfavorable for producing and rearing young (Newton 1979, Steenhof et al. 1997). These results are consistent with other long-term Golden Eagle studies (Brown and Watson 1964, Steenhof et al. 1997, Watson 1997).

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GOLDEN EAGLES IN A MULTIPLE LAND-USE ENVIRONMENT: A CASE STUDY IN CONFLICT MANAGEMENT

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Abstract.—Sheep farming and forestry dominate land use over much of western Scotland, and these activities have important implications for the nesting density and reproductive success of Golden Eagles (*Aquila chrysaetos*). In some areas, secondary land uses such as wind energy developments and opencast quarrying are being considered. The additive effects of such developments have prompted concern among conservationists that eagles will be adversely affected. In this paper, we summarize an approach used to investigate and reduce to acceptable levels the impacts of sheep, forestry, and a planned wind energy development on a territorial pair of eagles in the Kintyre peninsula. Site-specific studies of eagle ranging, diet, and prey distribution indicated: (1) eagle activity was greatest in a contiguous area of high elevation moorland that included part of the proposed wind farm; (2) eagles avoided forest habitats, except where the trees were young, or the stands were small; (3) avian prey, particularly Red Grouse (*Lagopus lagopus scoticus*), was an important component of diet during a summer in which the eagles bred successfully; and (4) an important population of Red Grouse occupied the proposed wind farm. We concluded that avoidance of the wind farm by eagles would result in the forfeiture of an important prey resource. Alternatively, in the absence of any modification of ranging behavior, eagles were at considerable risk of collision with wind turbines. This paradigm led us to develop a large-scale management scheme with the aim of reducing the cumulative impacts of the various land uses. A key objective of the scheme is to increase the overall number of grouse available to eagles. We intend to achieve this through the conversion of forest habitat to moorland and extensive management of sheep. Simultaneously, the scheme seeks to discourage eagles from entering the wind farm by impoverishing the local habitat for grouse. We suggest that secondary developments such as wind farms sometimes represent an opportunity to enhance landscapes that have been degraded by previous land use decisions.

Key Words: *Golden Eagle*; Aquila chrysaetos; *land use*; *wind energy*; *cumulative impacts*; *habitat management.*

Aguilas reales en un ambiente de multiples usos de la tierra: un caso de estudio en conflictos de manejo

Resúmen.—Las granjas de ovejas y la silvicultura dominan el uso de la tierra en la mayoría del oeste de Escocia, y estas actividades tienen importantes implicaciones para la densidad de anidación y éxito reproductivo de las águilas reales (*Aquila chrysaetos*). En algunas áreas, los usos secundarios de la tierra tales como proyectos de energía eólica y extracciones de cantera a cielo abierto están siendo considerados. Los efectos aditivos de tales desarrollos han incentivado la preocupación entre conservacionistas de que las águilas serán adversamente afectadas. En este articulo, sintetizamos una metodología usada para investigar y reducir a niveles aceptables el impacto de las ovejas, la silvicultura, y de un programa planificado de energía eólica sobre un par de águilas territoriales en la península de Kintyre. Estudios específicos en un sitio del rango de las águilas, su dieta, y la distribución de presas indican que: (1) la actividad de las águilas fue mayor en un área contigua a un brezal de gran elevación que incluía parte de la granja propuesta para energía eólica; (2) las águilas evitaban los hábitats boscosos, excepto donde los arboles eran jóvenes o donde las perchas eran pequeñas; (3) las aves presa, particularmente el urogallo rojo (*Lagopus lagopus scoticus*), fueron un importante componente de la dieta durante un verano en el cual las águilas se reprodujeron exitosamente; y (4) una población importante de urogallos rojos ocupaba la granja eólica propuesta. Concluimos que si las avitan águilas evitan las granjas eólicas esto podría resultar en la confiscación de una importante fuente de presas. Alternativamente, en la ausencia de alguna modificación en el comportamiento de rango, las águilas estaban en un riesgo considerable de colisión con las turbinas de viento. Este paradigma nos llevo a desarrollar un esquema de manejo a

gran escala con el propósito de reducir los impactos acumulativos de los diversos usos de la tierra. Un objetivo clave del esquema es incrementar el numero total de urogallos disponibles para las águilas. Nosotros tenemos la intención de lograr esto a través de la conversión de hábitats boscosos a brezales y del manejo extensivo de ovejas. Simultáneamente, el esquema busca desalentar el ingreso de las águilas a la granja de energía eólica reduciendo allí el hábitat local para los urogallos. Sugerimos que los desarrollos secundarios tales como las granjas eólicas algunas veces representan una oportunidad para dar relieve a los paisajes que han sido degradados por previas decisiones en el uso de la tierra.

[Traducción de César Márquez y Victor Vanegas]

Land-use change is often implicated in declines in Golden Eagle (*Aquila chrysaetos*) numbers in the uplands of Scotland (e.g., Marquiss et al. 1985, Watson 1992, 1997, Gregory 1996). In the past, attention has focused on changes in primary land use. These changes can be conspicuous, such as the planting of large areas of open ground with commercial plantations of mainly exotic conifer trees or insidious, as in the long-term degradation of habitat by grazing livestock and red deer (*Cervus elaphus*). In recent times, a number of schemes to catastrophically alter upland landscapes have been proposed. These plans usually involve modification of specific parts of the landscape and we, therefore, refer to them as secondary land-use changes. Examples include wind energy facilities and opencast quarrying. Such developments are often controversial because they have the potential to severely impact eagles, resulting in lengthy and adversarial debates between developers and conservationists. The development of wind energy in Scotland is still in its infancy, and the impacts on eagles are therefore unknown. Studies in the U.S. have shown that eagles are vulnerable to collision mortality (Orloff and Flannery 1992, PBRG 1997). However, the relevance of these studies is limited by crucial technical and ecological differences. In reality, impacts depend on the cumulative effects of new developments and the existing land uses. In many cases, the magnitude of impacts is significant mainly because the primary land uses are unsympathetic toward eagles. Impacts will vary regionally and locally depending on the effects and nature of primary land use and the specific location of any new developments.

Two primary land uses predominate in much of western Scotland: sheep grazing and forestry. Sheep provide eagles with a useful source of carrion, especially in winter, but suppress populations of important live prey such as Red Grouse (*Lagopus lagopus scoticus*) and mountain hares (*Lepus timidus*) by impoverishing the cover of heather and other ground vegetation (Thompson et al. 1988, Watson 1997). Eagle population density has been shown to vary in relation to the abundance of carrion, whereas reproductive success appears to be related to the availability of live prey (Watson et al. 1992). Afforested ground does not support sheep carrion and ultimately yields little if any suitable live prey (Marquiss et al. 1985). In any case, eagles generally avoid plantation forests because they are probably unable or unwilling to hunt prey amongst the closely-spaced trees (McGrady et al. 1997). Furthermore, forestry can fragment eagle territories by creating barriers which eagles are reluctant to cross.

Secondary land uses may reduce prey abundance, displace eagles, or both. Thus, eagles might be forced to occupy less suitable foraging and nesting areas, resulting in a decline in hunting and breeding success. Because secondary developments tend to be industrial in nature, with associated noise and human disturbance, displacement effects often extend well beyond the boundary of the site. In the case of wind energy, while displacement may be detrimental if it results in the loss of foraging habitat, it benefits eagles by lessening the risk that a bird will collide with rotating turbine blades.

In this paper, we summarize the approaches used to address cumulative land use impacts in relation to a proposal by ScottishPower to build a 30 MW wind energy facility in central Kintyre, west Scotland. The development involves the construction of 46 wind turbines (rotor blade length 45 m) within the territory of a resident pair of Golden Eagles, <2 km from the area used for nesting. The territory is dominated by a north–south ridge rising to 454 m elevation. The ground west of this ridge slopes gradually down to the sea, whereas the eastern slopes are steeper with several subsidiary ridges dividing deep valleys. The planned turbines are to be located between 350–450 m at the south end of the main ridge. The reproductive success of the eagle pair in recent years has been poor with only one young raised since 1990 (M. Gregory

pers. comm.). This is probably due to the fact that much of the foraging range is occupied by plantation forestry. Elsewhere on Kintyre, forest establishment has resulted in a substantial reduction in the number of pairs of breeding eagles (Gregory 1996, Watson 1997). Further loss of moorland habitat is therefore considered highly undesirable, since it might compromise the ability of the area to support a pair of eagles.

It is not our intention to present a detailed account of the studies undertaken, many of which are still in progress. Rather, we wish to show how our results to date have been used to define conservation goals and guide management practices aimed at reducing the impacts to an acceptable level. Our main objective is to establish the pattern of eagle ranging behavior, activity, diet, and prey distribution to show the relative importance of the area occupied by the proposed wind turbines.

RANGING BEHAVIOR

Systematic observations were undertaken from four discrete vantage points in 1997–99. Between them, these vantage points allowed us to observe eagles in an area of about 100 km^2. We observed eagles for approximately 50 hr during about 400 hr of observation. The time eagles spent within various spatial components of their territory was recorded. The data were adjusted to account for differences in observation time and overlap in visibility between vantage points. In addition, the routes followed by eagles were plotted onto 1: 25 000 scale maps, enabling us to identify terrain and habitat features important to eagles at a fine scale. We expected eagle behavior to vary seasonally and annually due to variations in the available prey. Observations were, therefore, stratified by season and undertaken in a year in which breeding was successful and a year in which it was not.

The time eagles spent perched and the distribution of plotted flight routes were used to construct a map that estimated the relative importance of different parts of the territory (Fig. 1). This indicated that activity was greatest in areas of high elevation where trees were absent. Therefore, eagles tended to follow unafforested ridgelines to the north and east of the proposed wind farm. Afforested areas exploited by eagles comprised either trees <8-yr-old in the western part of the territory or narrow strips of forest that divided unplanted ridges in the northern part. Eagles frequently used the northeastern part of the proposed wind farm, but the remainder of the site did not appear to be important. Despite this, use of the proposed wind farm was considered sufficient to cause significant concern due to the risk of displacement and collision. As a first step to reducing this potential impact, planned locations of turbines in the northeastern portion of the site were relocated to the southwestern part of the proposed wind farm.

DIET

Dietary analysis was undertaken using a sample of 68 pellets collected at known roost sites. Prey remains were identified to the lowest practical taxonomic level. The results suggested that little avian prey was taken in winter, when sheep and deer carrion were mostly eaten (Fig. 2). However, in the one successful breeding summer studied, birds were found to make a much greater contribution to the overall diet. Of the birds taken, Red Grouse were the most important prey in terms of biomass. Interestingly, in summers when no young were raised, the diet more closely resembled that in winter with few birds taken. Therefore, it appeared that birds are more important prey when eagles had young to feed than at other times.

PREY DISTRIBUTION

Initial surveys indicated that Red Grouse were the only potential live prey of any importance (Shepherd 1997, Madders unpubl. data). Subsequently, grouse territories were plotted during spring using dawn point counts (Watson and O'Hare 1979), and their distribution confirmed in August during searches for grouse broods with trained pointing dogs. The distribution of grouse was closely associated with the cover of heather (*Calluna vulgaris*), the main food of grouse. As a result, grouse abundance was greater at higher altitudes, where the development of heather was less affected by grazing sheep. We estimated that around 25 grouse territories were located within the proposed wind farm.

HABITAT MANAGEMENT

Rather than simply accept the idea that the wind farm would be detrimental to an already stressed pair of eagles, we argued that the development represented an opportunity to redress some of the territory's existing shortcomings (i.e., to lessen the impact of sheep and forestry). Accordingly, we devised an integrated habitat management scheme that aimed to increase the overall live prey base

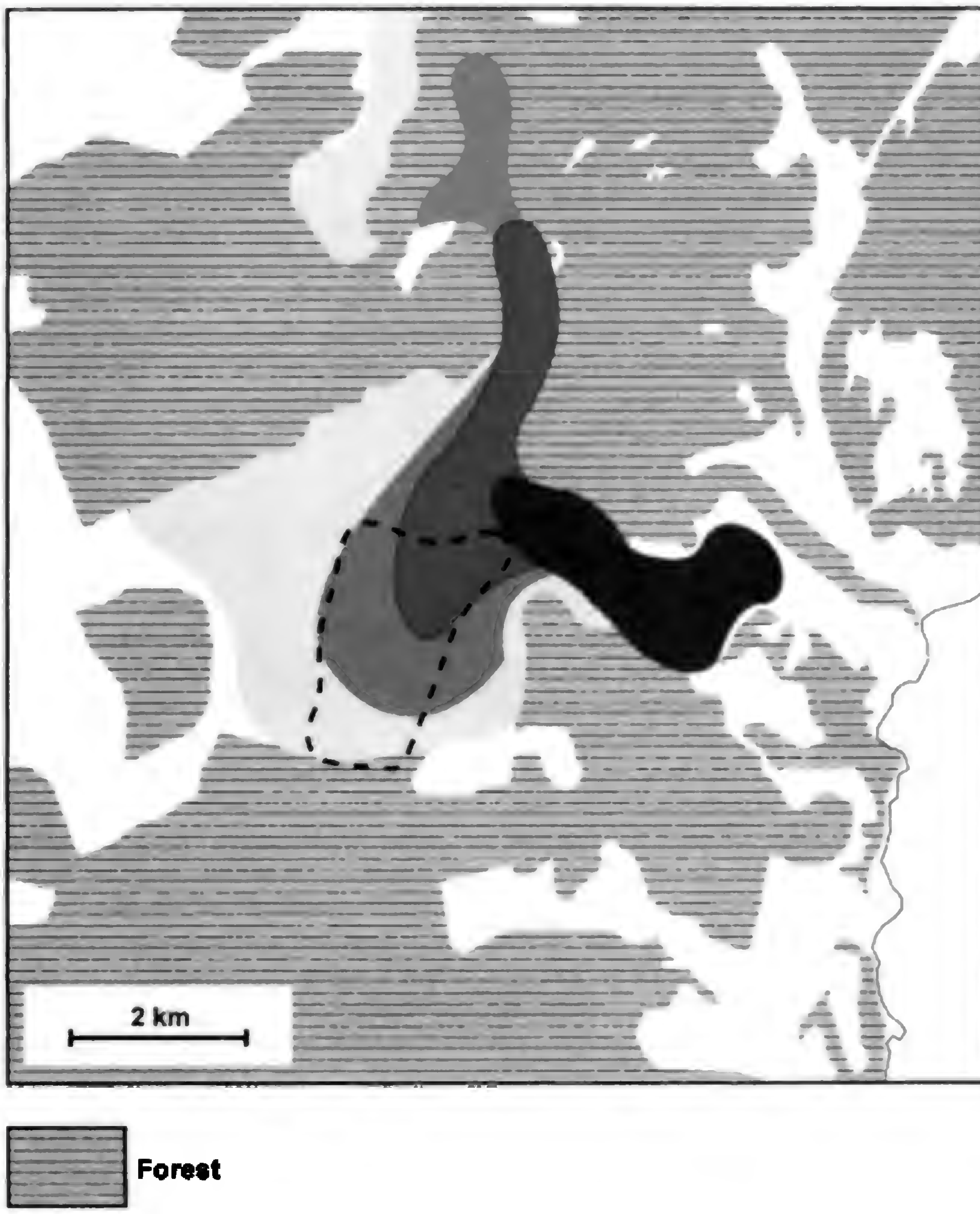

Figure 1. Diagrammatic representation of eagle ranging behavior 1997–99 showing the extent of forestry. Black and grey tones indicate the varying intensity of use by eagles (black = most used), based on the frequency with which eagles were observed to use different flight lines and perches during systematic timed observations. The broken line indicates the proposed location of the wind farm before revision of the turbine layout to accommodate eagles.

available to eagles (mainly Red Grouse), while simultaneously discouraging eagles from entering the wind farm. In other words, we wanted to improve breeding success and limit the risk of turbine collision.

The plan seeks to achieve these aims by increasing the cover and structural diversity of heather in the northern portion of the territory, thereby promoting a pattern of prey distribution that will encourage eagles to hunt outside the wind farm. Structural diversity is important because Red Grouse require a mosaic of short and tall heather between 5–40 cm for feeding and nesting (Moss 1989). An important objective is to provide a minimum of 22 additional pairs of Red Grouse. This is the estimated number of grouse that will become unavailable if eagles avoid the area occupied by the proposed wind turbines (INGENCO 2000). Effort will be concentrated on improving the habitat for grouse in areas adjacent to those already used intensively by eagles (Fig. 3). The principal features of the management plan include the conversion of

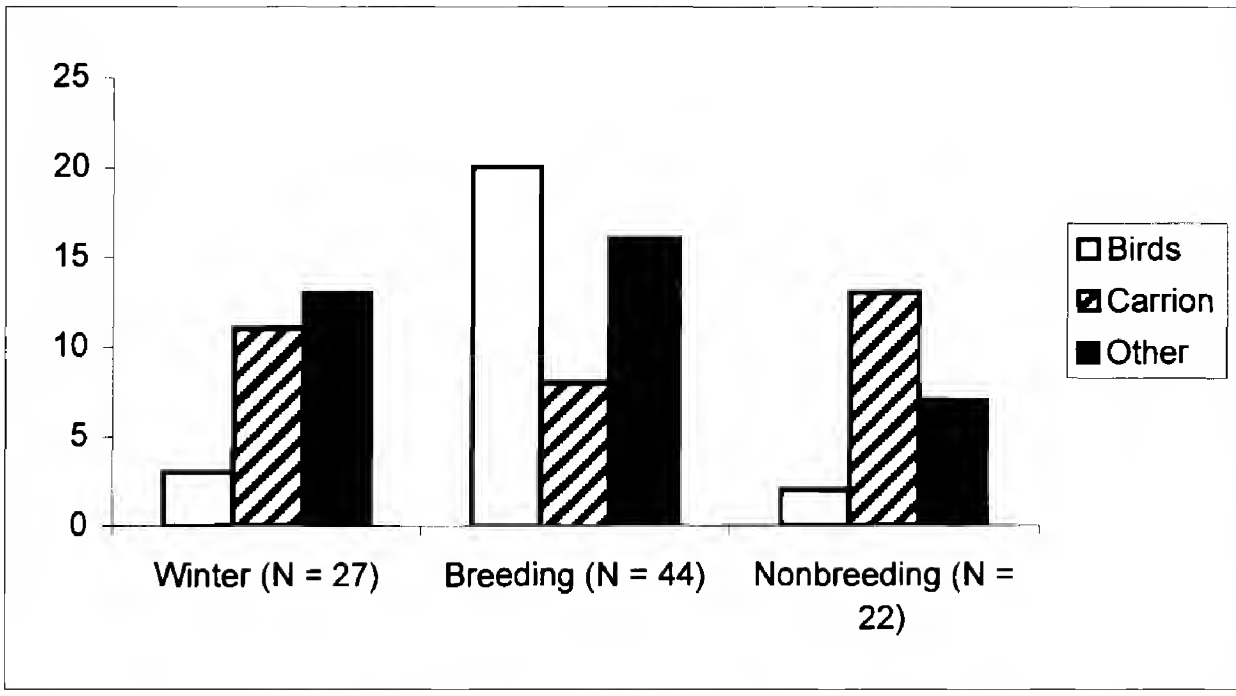

Figure 2. Diet of eagles during summer 1997 to winter 1998–99. The graph shows the number of occurrences of three prey types in pellets collected from roosts used by adult eagles (N = total occurrences in each group). Other prey included lagomorphs, field vole (*Microtus agrestis*), and hedgehog (*Erinaceus europaeus*).

450 ha of maturing coniferous forest to heather-dominated moorland. The trees to be felled occupy ridgelines and other high terrain. Trees will be cut using a mechanical flail and reduced to irregular-sized chips that will be distributed on site. Trials suggest that this approach causes minimal damage to the ground vegetation and does not suppress the subsequent development of heather. Felling operations began in September 1999 and it is anticipated that work will be completed by summer 2001.

The plan also includes the exclusion of sheep from 230 ha of moor where heather has been suppressed by grazing. Increased grazing of heather within the wind farm area will reduce the suitability of the habitat for grouse in the vicinity of the turbines. Carrion will also be removed from the wind farm and intensive shepherding will be undertaken outside the wind farm to prevent damage to areas of developing heather and achieve the required structural diversity within areas of established heather. Occasional cutting or burning of dense heather may be necessary to maintain a mosaic of habitat that provides grouse with both food and cover. We expect this approach to benefit not only grouse, but also mountain hare (*Lepus timidus*), a potentially important prey species that also feeds on heather (Hewson 1962). Significant benefits are also likely for ground-nesting raptors such as Hen Harriers (*Circus cyaneus*) and Merlins (*Falco columbarius*) that prefer to nest in dwarf shrub vegetation.

The management plan will have been in place for approximately two years by the time the turbines are erected. In addition, we wish to test a number of novel ideas for increasing live prey abundance. These include creating artificial warrens on low-lying grassland and establishing small populations of rabbits (*Oryctolagus cuniculus*). The scheme features a strong research component to generate information that will be useful in wider debates concerning upland management. For example, a study examining the process whereby heather becomes established on prematurely felled plantation forest is planned. A site ranger has been employed to undertake day to day management and research routines. In addition to monitoring eagle ranging behavior, annual surveys will measure the responses of vegetation and Red Grouse. We also intend to investigate the nature and extent of any avoidance behavior exhibited by eagles flying in the vicinity of the wind turbines.

CONCLUSIONS

What can we learn from this experience? First, we can learn that impact assessment needs to take into account the cumulative effects of existing and proposed land uses. Second, field research needs to be site specific, extensive, and detailed. The area occupied by the individuals potentially affected,

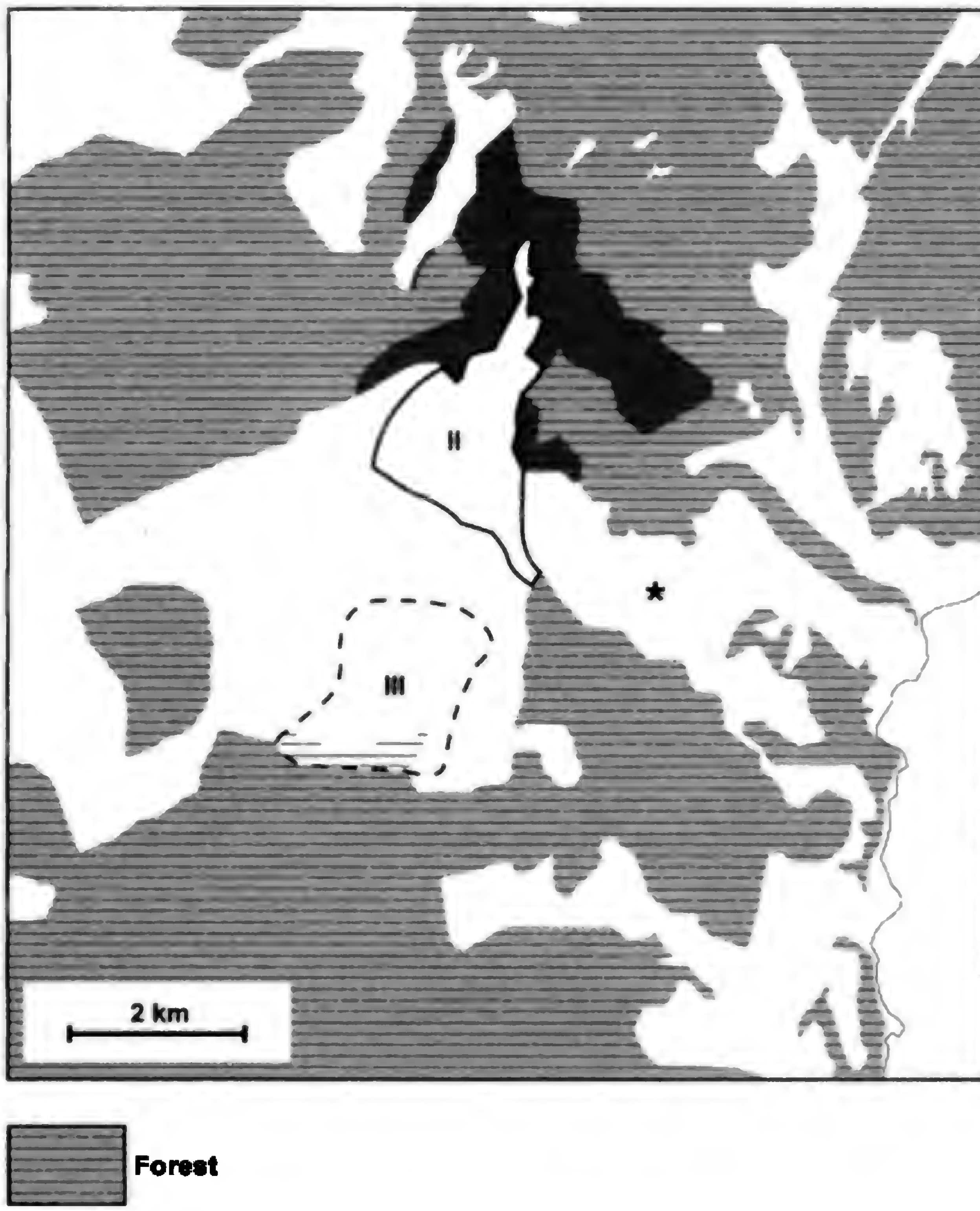

Figure 3. Summary map of proposed habitat management activities. Key: I = tree removal area; II = sheep exclosure area; III = modified location of wind farm, where increased grazing will reduce the abundance of eagle prey; * = area where grazing will be manipulated by intensive shepherding.

rather than the site proposed for development, should define the scale of study. Third, to be effective, mitigation must be done on a large-scale basis and provide habitat that is not only rich in prey but also appropriately distributed. Lastly, we can learn that developments can, in some circumstances and where the developer is willing, provide an opportunity to enhance degraded landscapes for the benefit of eagles and other raptors.

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A MODEL OF GOLDEN EAGLE (*AQUILA CHRYSAETOS*) RANGING BEHAVIOR

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Abstract.—Eight territory-holding adult Golden Eagles (*Aquila chrysaetos*) were radiotracked in all seasons from 1991–96 in western Scotland. Mean territory size was 6827 ha (range = 2604–12 835 ha). Core areas (50% of locations) used by tracked eagles averaged 498 ha. Tracked eagles moved up to 9 km from the center of their territories, but over 98% of observations were <6 km of the center. Log-linear models showed no significant preference for land cover, although relative use suggested the order of preference by eagles to be: montane > heather > coarse grassland > bracken > smooth grassland > bog > broad-leaved forests > pre-thicket forest > post-thicket forest > pasture > other habitats. Elevations ranged from sea level to 900 m but eagles appeared to prefer elevations between 150–549 m. Based on data from these eagles, we constructed a simple model to define likely boundaries of territories and to identify areas within those boundaries that are likely to be important to eagles. Features of the model included range centers identified from nest locations and nest-use data, boundaries with near-neighbors halfway between respective nest centers, and a 6-km cutoff in directions where neighbors were distant. The model designated core areas 2–3 km in radii using information on local eagle nesting density. Outside core areas, low elevations were avoided. We discuss the advantages and shortcomings of the model and its robustness when exported to other parts of Scotland.

Key Words: *Golden Eagle;* Aquila chrysaetos; *range; movements; territoriality; Scotland.*

Un modelo del rango de comportamiento del águila real (*Aquila chrysaetos*)

Resúmen.—Nueve águilas reales (*Aquila chrysaetos*) adultas poseedoras de territorios fueron rastreadas con radios en todas las estaciones desde 1991–96 en el oeste de Escocia. El tamaño medio de los territorios fue 6827 ha (rango = 2604–12 835 ha). Las áreas centrales (50% de las localizaciones) usadas por las águilas rastreadas promediaron 498 ha. Las águilas rastreadas se movieron por eucima de 9 km desde el centro de sus territorios, pero mas del 98% de las observaciones estuvieron a <6 km del centro. Dos modelos de Logaritmo linear no mostraron preferencias significativas para la cobertura terrestre, aunque el uso relativo sugiere el orden de preferencia para águilas asi: montano > brezal > pastizales toscos > helechos > pastizales finos > pantanos > bosques de hoja ancha > bosque pre-matorral > Bosques post-matorral > pasturas > otros hábitats. Las elevaciones variaron desde el nivel del mar hasta 900 m pero pareció que las águilas prefieren elevaciones entre 150–549 m. Con base en los datos de estas águilas, construimos un modelo simple para definir los límites probables de los territorios y para identificar áreas dentro de aquellos límites que probablemente son importantes para las águilas. Las características del modelo incluían los centros de los rangos identificados a partir de la localización de los nidos, los datos del uso de los nidos, los limites con los vecinos mas cercanos a mitad del camino entre los respectivos centros de sus nidos, y un corte de 6 km en las direcciones donde los vecinos no fueron claramente conocidos. El modelo designó áreas núcleo de 2–3 km de radio usando información sobre la densidad local de anidación de la águilas. Afuera de las áreas núcleo, las bajas elevaciones

fueron evitadas. Nosotros discutimos las ventajas y deficiencias del modelo y su robustez cuando es extrapolado a otras partes de Escocia.

[Traducción de César Márquez y Victor Vanegas]

In the British Isles, the breeding range of Golden Eagles (*Aquila chrysaetos*) has been much reduced. Today, Golden Eagles are found primarily in the Highlands of Scotland, although a few pairs breed in southwestern Scotland and northern England (Watson and Dennis 1992, Gibbons et al. 1993, Green 1996). In recent years, numbers of breeding Golden Eagles in Britain have been stable at about 425 pairs, although regional fluctuations have occurred (Dennis et al. 1984, Green 1996).

Afforestation of parts of upland Scotland has had a large effect on the habitat of the country. Preliminary studies have associated large-scale afforestation with the decline in the numbers of breeding eagles in western Scotland (Watson et al. 1987), and breeding success in western and southwestern Scotland (Marquiss et al. 1985, Watson 1992) has been shown to be dependent on afforestation. Watson et al. (1987) predicted that forestry would have a negative effect on eagles if it exceeded 40% of the area within 4 km of the center of an eagle's territory.

The Golden Eagle is an "amber list" species of medium conservation concern in the United Kingdom (Gibbons et al. 1996), because it has an unfavorable conservation status in Europe due to its rarity (Tucker and Heath 1994). The European population amounts to 5000–7200 pairs of which 5.8–8.4% are in the United Kingdom.

Between 1991–96, the Royal Society for the Protection of Birds (RSPB), working with the Research Division of the Forestry Commission, conducted a study of the ranging behavior of Golden Eagles in Argyll, Scotland. The primary aim of this study was to capture and fit backpack-mounted radiotransmitters to free-flying eagles and to follow their movements, and then to relate these data to both land cover and land use. As a product of this research, a simple model mapping eagle ranging behavior was constructed. The advantages of this mapping model are that it is easy to use, requires that the user has little *a priori* knowledge of eagles in general or of particular pairs, and is robust even when information on eagle pairs is limited. The mapping model was published as a Research Information Note by the Forestry Commission in the United Kingdom (McGrady et al. 1997). This paper presents the mapping model and discusses its advantages and shortcomings.

Study Area and Methods

The study area covered about 500 km^2 in mid- and south Argyll, Scotland (Fig. 1). Both fresh and saltwater lochs are present, and the topography is hilly, with some peaks over 950 m. In general, the agricultural potential of the area is limited, with most land being capable of supporting only rough grazing and plantation forestry Some agricultural improvement has occurred such as drainage and fertilizing but this is generally limited to areas at lower altitudes.

Purple moor grass (*Molinia caerulia*) and white bent (*Nardus stricta*) dominate the areas grazed by sheep, and there are areas of poor condition dwarf-shrub heath. In some areas, bracken (*Pteridium aquilinum*) cover is extensive. Large and small blocks of commercial coniferous plantation (mostly *Picea sitchensis*) are quite common.

In terms of land use, sheep rearing and forest plantations are the predominant forms of land use. Some deer stalking is pursued but there is relatively little management of moors for Red Grouse (*Lagopus lagopus scoticus*) Watson et al. (1987) reported a general decline in grouse stocks in the area due to overgrazing.

Land cover, land use, terrain, and precipitation vary from region to region within the breeding range of Golden Eagles in Scotland. In general, the east mainland including the Cairngorms is drier, with higher elevation, and supports relatively more grouse moor and relatively less sheep rearing than in the west mainland. The islands of the Hebrides are also variable. Their climate is oceanic and few grouse are present.

Eagles were trapped in funnel traps and using a power snare (McGrady and Grant 1996). Transmitters were fitted as backpacks with a degradable link. They weighed 45 g and had a potential life of up to 4 yr. There was no evidence that the tagging of eagles, even both members of a pair, affected breeding or any other activities, and some eagles fitted with tags have bred in years after being instrumented.

Normally, tracking was done by at least two people in radio communication with one another. Immediately after fitting an eagle with a transmitter, it was followed intensively to make sure that it was able to fly properly After some days, birds newly fitted with transmitters were worked into the rotation of radio monitoring; thereafter they were visited as often as possible on a regular basis Because of logistical constraints, it was unusual to track eagles in more than one territory per day.

Birds were tracked using a directional (yagi) antenna and a compass to generate a bearing of the eagle's direction. From this, we could triangulate and estimate the location of the eagle. Our minimum aim was to get one high quality location (<100 m accuracy) per day of tracking. We often exceeded this aim. Because the most accurate locations were not from triangulation but from

Figure 1. Study area in western Scotland.

direct observations, we aimed to visually locate eagles. Once in view, we would observe eagles throughout the day, mapping their movements. Our observation locations were chosen so that we were able to record ranging of the eagles without influencing their movements. When eagles moved from our view, we would search for them, establish new observation points, and map their locations. Often, we had more than one eagle in view because all instrumented birds were paired.

In the analyses, we used only locations known to be <100 m accurate. Data were sorted to promote independence between fixes. Analysis suggested that fixes from any one individual eagle should be separated by >20 min to ensure independence; we separated successive locations by at least 1 hr.

We used MacAulay Land Use Research Institute (MLURI) Land Cover Scotland 1988 (LCS88) (MacAulay Land Use Research Institute 1989) data augmented by maps from Forestry Commission and private forestry companies to map land cover. Fifty-six LCS88 land cover types were found within Golden Eagle ranges. These types were aggregated by shared primary land cover feature into 16 land cover types: wetlands, coarse grassland, smooth grassland with scrub, smooth grassland without scrub, water, anthropogenic, salt marsh, cliff, bracken, grass, heather, montane, improved pasture, pre-thicket

forest/low scrub, post-thicket forest, and broadleaf forest. Details of the terrain were recorded on a digital terrain map using a Geographic Information System (GIS).

Preference for land cover types or elevation was analyzed using Generalized Linear Modeling (GLIM) procedures, and the approach used was that used by Heisey (1985). GLIM output yields estimates of the standard errors of individual values of habitat use, and the statistical significance of the variation in relative density among land cover or elevation can be estimated by a randomization test (Manly 1991). A score was calculated, which described the variation among the relative density values for each habitat. Using the higher of either the expected or observed number of locations as a weighting, the labels of the habitats found in each home range were shuffled. The log-linear model was then fitted to the randomized data and the variation score was compared with that from the real data. Randomization was performed 1000 times and the number of times the score was greater than the real score was used to obtain P values. Because response variables were counts, we tested errors against a Poisson distribution and used a log link (Crawley 1993).

In creating the model to map eagle ranges, we looked for features of ranging that were common to all birds. We attempted to make the model easy to use requiring little *a priori* knowledge of eagles or the area in which the model was applied.

RESULTS

We fitted 11 eagles with radiotransmitters. A total of 8 territory-holding adult eagles was radiotracked in all seasons from 1991–96. Because of radio failure, only seven adults provided enough data to analyze ranging behavior. We estimated the Minimum Convex Polygon (MCP) home range to be 7384 ha (range = 3967–12 835 ha). Core areas based on 50% of locations averaged 481 ± 192.3 (±SD) ha.

Based on consistent habitat use patterns among eagles, we developed a model for eagle ranging behavior based on the following features:

Range Centroid. The center of ranging was described by the harmonic mean center of ranging points. For any individual, this location was influenced by factors including terrain, distribution of prey, dominant wind conditions, season, year, near-neighbor distance, and breeding status. The ranging center could be estimated by using the location of the nesting site and the mean of all nesting sites was a good surrogate for the center of ranging (mean distance between mean of nest sites and harmonic mean of ranging locations = 26.8 ± 22.6 m, N = 7). By weighting the mean in accordance with recent use of particular nests, this estimate was improved (mean distance between weighted mean of nest sites and harmonic mean of ranging locations = 10.65 ± 7.45 m, N = 7). Even when terrain clustered nests, the mean of each cluster gave good estimates of range centroids with multiple centers of activity. By identifying clusters of nests in one range and calculating two centroids from nest locations, the difference between harmonic mean locations and centroids for all eagles averaged <10 m.

Range Boundaries. Eagles could potentially range very far. However, in our study, they stayed within a 9 km radius of the centroid (Fig. 2). In most ranges, eagles were constrained by near neighbor, terrain features, or inappropriate habitat so they did not range equally in all directions. Ninety-eight percent of all locations were within 6 km of range centers.

Eagles are territorial and generally try to exclude intruding eagles, especially during prebreeding and breeding. When centroids of nearest neighbors were <12 km, the boundary between territories was a line equidistant from the two centroids.

Core Area and Centricity. All radiotracked eagles had core areas or places where >50% of locations occurred. In our study, core areas were all within 3 km of centroids. In general, core areas were smaller in areas where breeding density was highest. When plotted, the relationship between core area and local eagle density was inverse, and almost a straight line. We had too few data to test the significance of this relationship because we did not include ranges that were coastal or did not have neighbors in all directions.

An extension of the core area feature was that eagles used areas that were farther from the center of the range less than we expected. Figure 2 shows the distribution of eagle locations 0.5–6 km from the harmonic mean center, in relation to the amount of land available (open water areas excluded). Therefore, all other things being equal, if two areas of similar habitat were considered, the one closest to the range center would be the one most used by eagles.

Elevation Cut Off. Eagles showed significant selection of elevations between 150–550 m in western Scotland (Fig. 3).

Terrain. Eagles appeared to use certain terrain features more than others. Terrain features such as slope and aspect, along with wind direction and speed, determined places where updrafts were produced, and where soaring conditions are most favorable.

Landcover. Analysis of land cover choice by ea-

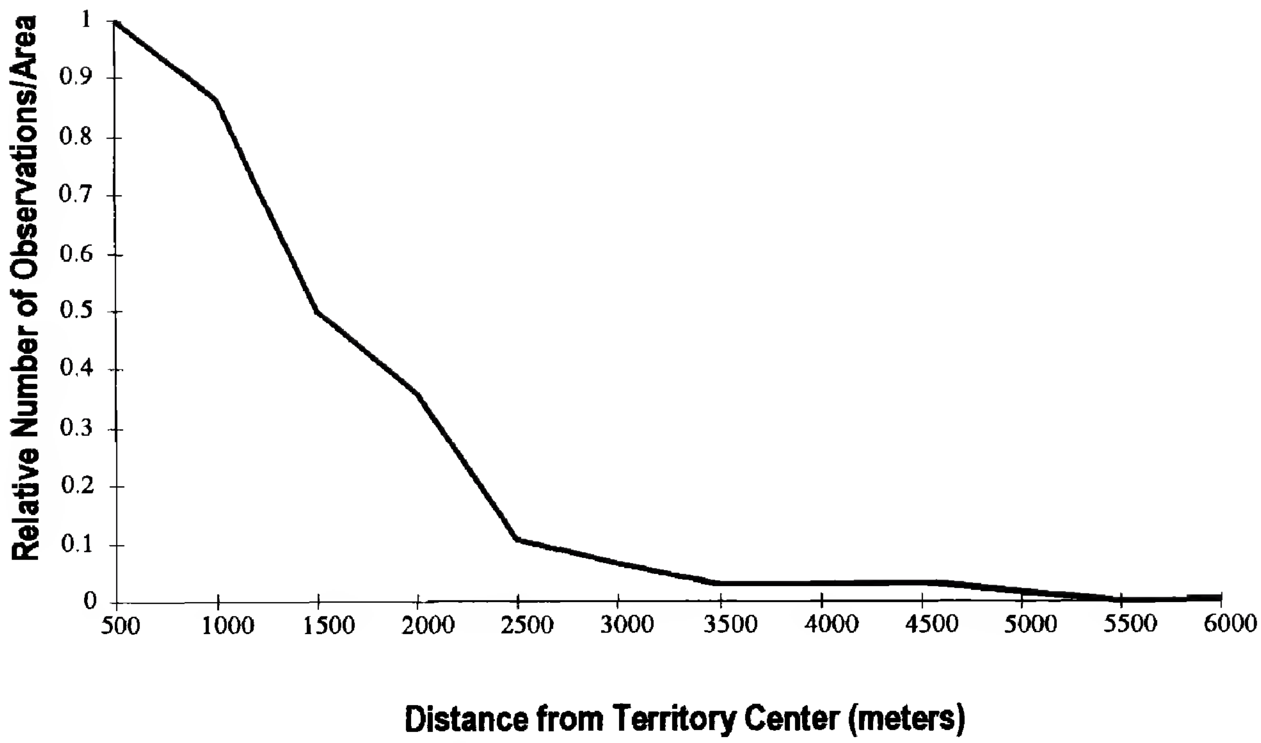

Figure 2. Relative density of Golden Eagle ranging locations in relation to available land area at different distances from the range center (harmonic mean). Number of territories = 6, number of eagles = 9, number of observations = 815).

gles showed there to be no significant selection of land cover types by eagles (Fig. 4). We ranked the most preferred to least preferred land cover types as follows: montane > heather > coarse grassland > bracken > smooth grassland with scrub > bog > broadleaved forest > pre-thicket forest/low scrub > post-thicket forest > improved pasture > water > anthropogenic > smooth grassland without scrub > salt marsh > wetlands > cliff. By further aggregating similar habitats, the rank of most

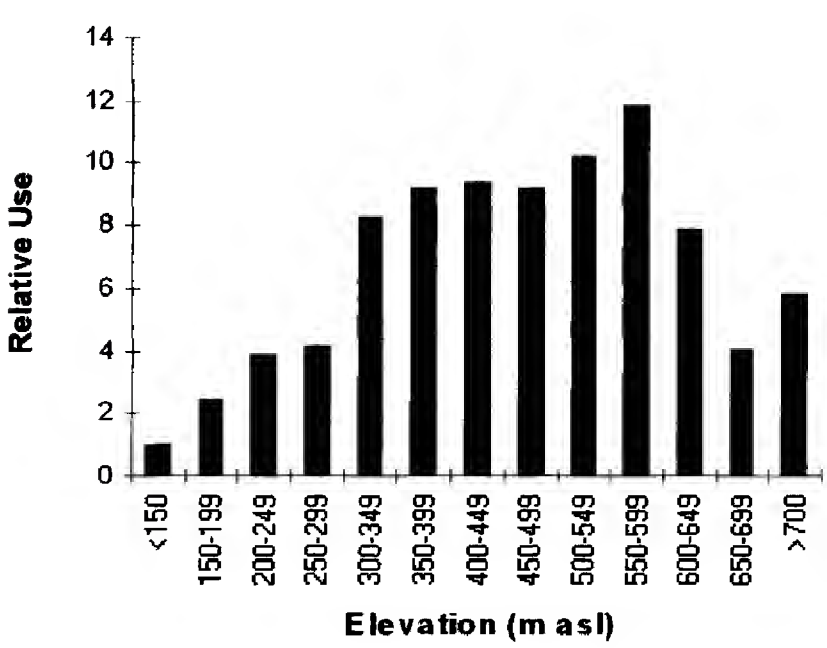

Figure 3. Relative use of elevation bands (from GLIM) within ranges by Golden Eagles in western Scotland. Number of territories = 6, number of eagles = 9, number of observations = 815).

preferred to least preferred landcover was: montane > grass > heather > high forest > bog > pre-thicket forest > other woodland > water. The main feature to note was that habitats most used by Golden Eagles were open ones, and the less used habitats were those that were either closed (i.e., had trees), those where human disturbance was likely, or those that had no hunting potential (i.e., water). Low use of cliff areas might have been a product of cliffs being difficult to interpret and map from the aerial photographs used to create LCS88.

Using the Model. The model requires some knowledge of the location of nesting places of eagles. From this, the model allows one to draw likely boundaries and estimate core areas of Golden Eagles in Scotland (Table 1). Our analysis also provides guidance to interpreting which areas within the model boundaries are most likely to be favored by eagles.

DISCUSSION

To date, our model has proven to be a useful starting point in discussions between developers, conservation agencies, and land-use regulators. For all parties, it has been useful in identifying areas in which conservation concerns are greatest for Golden Eagles, and has therefore concentrated discussions on areas whose loss would most likely impact eagles. It has provided the basis for the de-

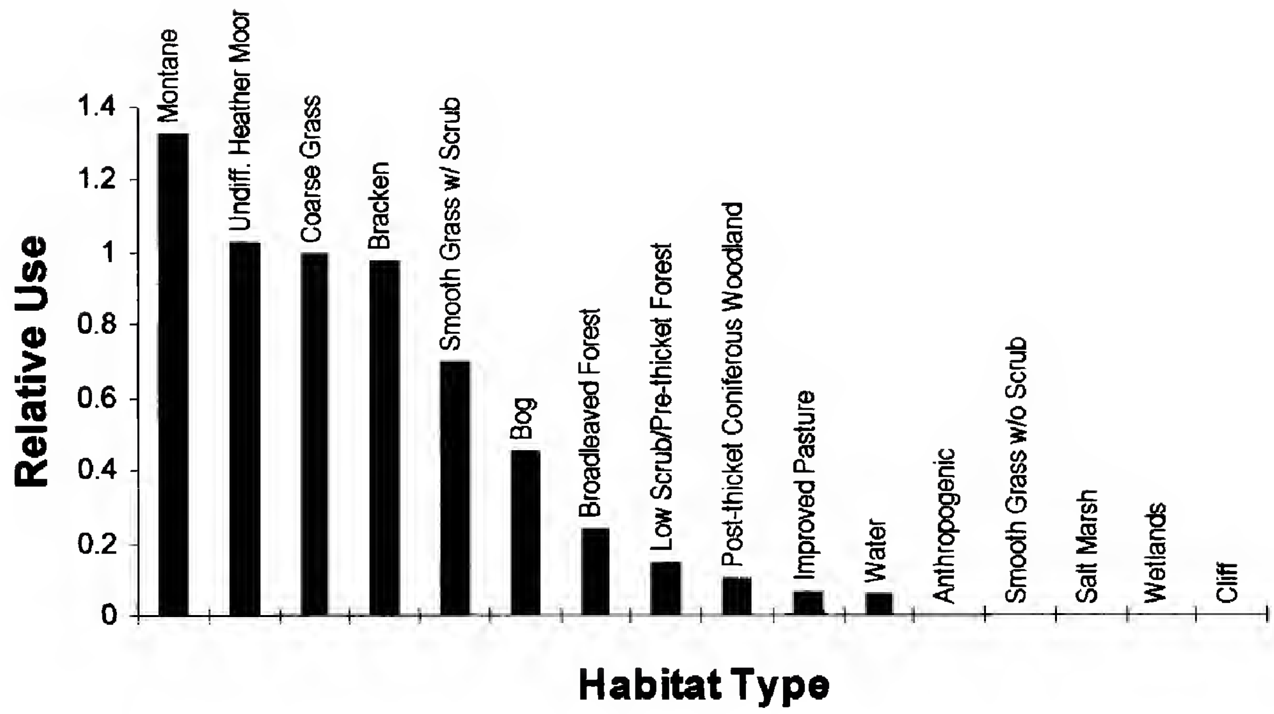

Figure 4. Preferences for land cover types shown by radiotagged Golden Eagles in western Scotland. Y-axis is the relative preference (from GLIM) for each habitat type.

velopment of new models that take into account elevation, distance from centroid, and terrain to better predict use of areas by eagles, especially those that are outside the core (Whitfield et al. 2001).

When compared to maps drawn by local eagle experts from other parts of Scotland, the model predicts core area and range boundaries very accurately (McGrady unpubl. data). Predictions of the use of various elevations by eagles appear to be most accurate in areas with topography similar to our study area. Although the model can give good estimates of range boundaries and core areas, interpreting the variance between the model and actual eagle ranging is best done with some knowledge of eagles in general and local knowledge of individual eagles. This is true also for interpreting our analyses where features of eagle ranging are not so clear-cut, such as habitat selection. Boundaries were not solid barriers and specific terrain could shift them somewhat with the direction of the shift influenced by wind direction and velocity that might change which neighboring pairs have the most advantageous soaring conditions. Territoriality is not 100% efficient, so unchallenged intrusions did occur, but in general the intrusions between neighbors were never deep into adjacent ranges.

Based on direct observational data from other areas in Scotland where elevation is different than in our study area, it appeared that this elevation preference may be scaled according to the overall elevation of the range. In areas where ranges are at relatively high elevation (e.g., Cairngorms), the cutoff appeared to occur at about 150 m above the valley floor. In lower-lying areas (e.g., coastal sites on Hebridean islands), there appeared to be no elevation cutoff and eagles used all elevations.

In general, our examination of the use of land cover was related to its importance as habitat for potential prey for eagles. In other countries, where updrafts produced by solar radiation are important, certain types of land cover (e.g., scree) are favored (Brendel pers. comm.).

Although our model has proven to be a good guide to eagle range use, in places where there is local expertise on particular pairs, the model should be used within the context of that expertise. Although the model has been robust enough to prove a good predictor of eagle range boundaries in other parts of Scotland, there are some ranges where it does not perform well. These ranges do not have neighbors on all sides and have prey that is concentrated in areas away from the core area. These situations can result in eagles ranging farther than predicted and being found more often than expected outside of the model's core area.

There are instances where we believe the model has been inappropriately applied when not used in the context of local knowledge of eagle ranges. The extent of this problem is unknown. It is true that local knowledge of eagles may be somewhat biased because of the way in which the data were collected. Despite this, data gathered by local ex-

Table 1. Steps involved in the use of the Golden Eagle ranging model.

STEP 1. FINDING THE RANGE CENTER	The range center is best calculated from the mean position of nests used in the past 10 yr, but lacking these data use the mean position of all nests. If the same nest is used on three occasions, enter its location three times into the calculation of the mean. In some territories, geographical features cause nests to fall into separate clusters. In these, the mean position of each nest cluster should be calculated, and if their centers are ≥2 km apart, then the range will contain more than one center.
STEP 2. DETERMINING THE CORE AREA	The core area (where eagles spend 50% of their time) can be estimated by a circle around the range center with a radius of 2–3 km. The distance that best estimates the core area is a reflection of territory quality, prey distribution, and geographical features. In general, one would expect territories with abundant prey to have smaller core areas, and those with much unsuitable habitat (including plantation forest) or low prey densities to have larger core areas.
STEP 3. DETERMINING THE TERRITORY BOUNDARY WITH NEAR-NEIGHBORING EAGLES	To estimate the territory boundaries between two neighboring pairs of eagles whose nest centers are <12 km apart: (1) draw a straight line joining the two range centers, (2) find a point on this line halfway between centers, (3) draw a line through the halfway point at right angles to the first line. To estimate the boundary with other neighbors repeat these steps until the line drawn forms a polygon around the range center. The strength with which this boundary is defended decreases as one moves away from range center, and varies with season. The exact position of this boundary may vary with topographical features and windflow that produce favorable flying conditions.
STEP 4. DETERMINING THE TERRITORY BOUNDARY WHERE THERE ARE NO NEAR-NEIGHBORING EAGLES	Most eagle territories extend 6 km from the range center. Some eagles will use areas up to 9 km from their range center in the absence of neighbors or geographical boundaries. To determine the boundary, draw a curved line at 6 km radius from the range center to connect adjacent boundary lines drawn in Step 3. Eagles travelling farther are usually making use of a reliable source of food, such as a rabbit warren or a carcass, in areas not occupied by neighboring eagles.
STEP 5. USING AN ALTITUDE CUTOFF	In Scotland, eagle territories can be grouped as high altitude (e.g., Cairngorms), medium altitude (e.g., mainland Argyll), or low altitude (e.g., Isle of Mull). Eagles in medium and high altitude territories avoid low ground. For medium altitude territories, use an altitude cutoff at 150 m outside the core area, but include all altitudes within the core area. Use this rule in conjunction with steps 3 and 4 to delineate the outer edge of the eagle territory. High altitude territories exhibit an altitude cutoff outside the core area of 150–200 m above the valley floor. In low-lying coastal territories, eagles can use all altitudes except areas with a high level of human activity. Particularly in high and low altitude territories, local information is crucial to decide that altitude cutoff to use.

perts often provide critical information by which the results of the model should be interpreted. In some cases, data gathered by local experts can be analyzed carefully to lessen the influence of biases.

The basis of the model is the location of nests. This information is often closely held by eagle workers, conservation groups, and government agencies. There is a suspicion in the minds of some that the model should not be used by anyone other than those normally privy to this information. Of course, developers, foresters, landowners, and farmers are reluctant to accept judgments on land use change applications that are not totally transparent and open to discussion and negotiation.

Although we have not undertaken an exhaustive or systematic study of whether this model works

elsewhere, where we have applied it in other places in the world, it has performed surprisingly well. It may be that some of the basic features of this model are the result of Golden Eagle energy budgets and the cost of efficiently maintaining a pair bond and territory.

ACKNOWLEDGMENTS

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IMPROVING PREDICTION OF GOLDEN EAGLE (*AQUILA CHRYSAETOS*) RANGING IN WESTERN SCOTLAND USING GIS AND TERRAIN MODELING

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Abstract.—A current model for predicting range use of Golden Eagles (*Aquila chrysaetos*) in western Scotland is derived from observed ranging behavior, a central point, and elevation. An improvement to this model is described that incorporates terrain features. Ridges are modeled as an assumed surrogate for deflected updrafts of air currents. Golden Eagles preferred areas close to ridges and close to the center of the range described by mean nest site location in the past 10 yr. The new model is an assemblage of the observed relationships between ranging points and the range center and ridge features, with an elevation cutoff, applied to a locally-derived range center and range boundary.

Key Words: *Golden Eagle*; Aquila chrysaetos; *home range*; *ranging behavior*; *range model.*

Mejorando la predicción del rango del águila real (*Aquila chrysaetos*) en el oeste de Escocia usando SIG y modelamiento de terrenos

Resúmen.—El modelo actual para predecir el uso del rango del águila real (*Aquila chrysaetos*) en el oeste de Escocia se deriva del comportamiento de rango observado, un punto central, y la elevación. Se describe un mejoramiento a este modelo incorporando las características del terreno. Las cordilleras son modeladas como un sustituto adoptado para desviar los movimientos ascendentes de las corrientes de aire. Las águilas reales prefieren áreas cercanas a las cordilleras y cerca al centro del rango descrito por la media de la localización del sitio nido en los últimos 10 años. El nuevo modelo es un ensamblaje de las relaciones observadas entre los puntos del rango, el centro del rango y las características de las cordilleras, con un corte en la elevación, aplicado a un centro de rango derivado localmente y a un limite de rango.

[Traducción de César Márquez y Victor Vanegas]

The conversion of large tracts of open upland habitat to plantations of dense stands of conifer trees is one of the most significant land-use changes in Scotland over the last 50 yr (Avery and Leslie 1990). Concern over these changes prompted several studies of the effects of commercial forestry on birds, including the Golden Eagle (*Aquila chrysaetos*) (Marquiss et al. 1985, Watson et al. 1987, Watson 1992). This work demonstrated a link between reduced breeding success of eagles and commercial tree planting and suggested that breeding pairs may abandon ranges if extensive planting occurred close to range centers.

McGrady et al. (1997) evaluated the impact of forestry on Golden Eagles by systematically collecting observations of Golden Eagle range use by radiotagged birds in Argyll, Scotland. Their aim was to explicitly identify important areas for eagles and to develop a generalized range prediction model so that future forestry proposals could be judged for their likely impacts on eagle ranging where data on range use did not exist. This model is commonly known as the RIN model after the series of Research Information Notes in which it was published. It provides a simple prescription to estimate the likely boundaries and the core area of an eagle range based on knowledge of the range center, described by the average nest site location, and the

centers of neighboring ranges. While eagles may range 6–9 km from their range centers, the "core area" of the range is within 2–3 km of the range center and represents the area where eagles are expected to spend 50% of their time. The model also gave general guidance on where to site new forest planting. It suggested that tree planting in core areas could be detrimental to eagles, and that such planting usually should be avoided or at least kept below the 40% of landcover within 4 km level indicated by Watson et al. (1987) as having a negative impact on eagles. It also recommended that plantings in low areas had less impact on eagles than those at middle elevations.

The simplicity of the RIN model and its foundation in field observations, together with the growing recognition of the need to protect Golden Eagles away from designated protected sites in the "wider countryside" (Watson and Whitfield, this volume), has led to its increasing adoption by foresters and conservationists alike. This paper describes some of the results of ongoing research to improve modeling techniques for predicting Golden Eagle ranging behavior using a Geographic Information System (GIS). It also illustrates several areas of conservation management where the predictive capabilities of range modeling could be applied and suggests further directions for model development. Here, we present a simple overview of the direction of this range modeling. More detailed information (McLeod and Whitfield 1999) and results are published elsewhere (Whitfield et al. 2001).

MODEL DEVELOPMENT

Development of a range prediction model requires data on known ranging behavior, coupled with data on environmental factors, including physical features of eagle ranges. If ranging behavior is affected by environmental factors, then it should be possible to predict behavior from knowledge of the environmental factors alone. The success of the predictive model will depend on the strength of association between behavior and environment and how successfully the environmental factors to which Golden Eagles respond can be incorporated into the model.

DATA ON RANGING BEHAVIOR

The modeling process described here employs the same ranging data used to derive the RIN model (McGrady et al. 1997). The field study area was north Argyll in the western Highlands of Scotland (Fig. 1). From 1992–96, 9 adult Golden Eagles were radiotagged in six home ranges and tracked Birds were located with the aid of the radio tags and triangulated visual sightings were made by at least two observers and recorded relative to geographical location as X-Y coordinates. One day constituted an observation session. Out of each session, a location was chosen randomly for inclusion in the analysis. Additional points within a session were used if they were >1 hr earlier or 1 hr later than the original random location. This process was repeated until selection spanned the entire day-long observation period and had included all observation days. Only records during the non-breeding period were included in the analysis, and if both birds in a pair were tagged, the combined observations were used to define the overall range of the pair (Marzluff et al. 1997). An example of the range use data is illustrated in Fig. 2. It was not known if the radio tags affected range use, although no effect was obvious.

ENVIRONMENTAL FACTORS: RANGE CENTER AND BOUNDARIES

Observations were clustered around a few localities, notably a "central" area within 2–3 km of nests and were distance-limited in distribution (i.e., over 98% of range use observations were within 6 km of the range center) (Fig. 2). The environmental factor that provided the best fit to the home range center was the mean nest location within the past 10 yr (McGrady et al. 1997). Eagle locations were generally closer to the range center when other territories were immediately adjacent. Hence, when neighboring range centers were <12 km apart, range boundaries could be estimated reasonably by delineating equidistant points between adjacent range centers. In the absence of neighbors, we estimated range boundaries at 6 km from range centers (McGrady et al. 1997). These two environmental factors, range center and influences on range boundary, are fundamental to both the RIN model and the new modeling direction, and their influence is assumed for present purposes (McGrady et al. 1997). Even though the new model is founded in and represents an extension of the RIN model, to differentiate it from the RIN model, it is called the PAT (Predicting *Aquila* [*chrysaetos*] Territory) hereafter.

ENVIRONMENTAL FACTORS: TERRAIN

Golden Eagles are large birds that exploit air currents for much of their activity (Watson 1997),

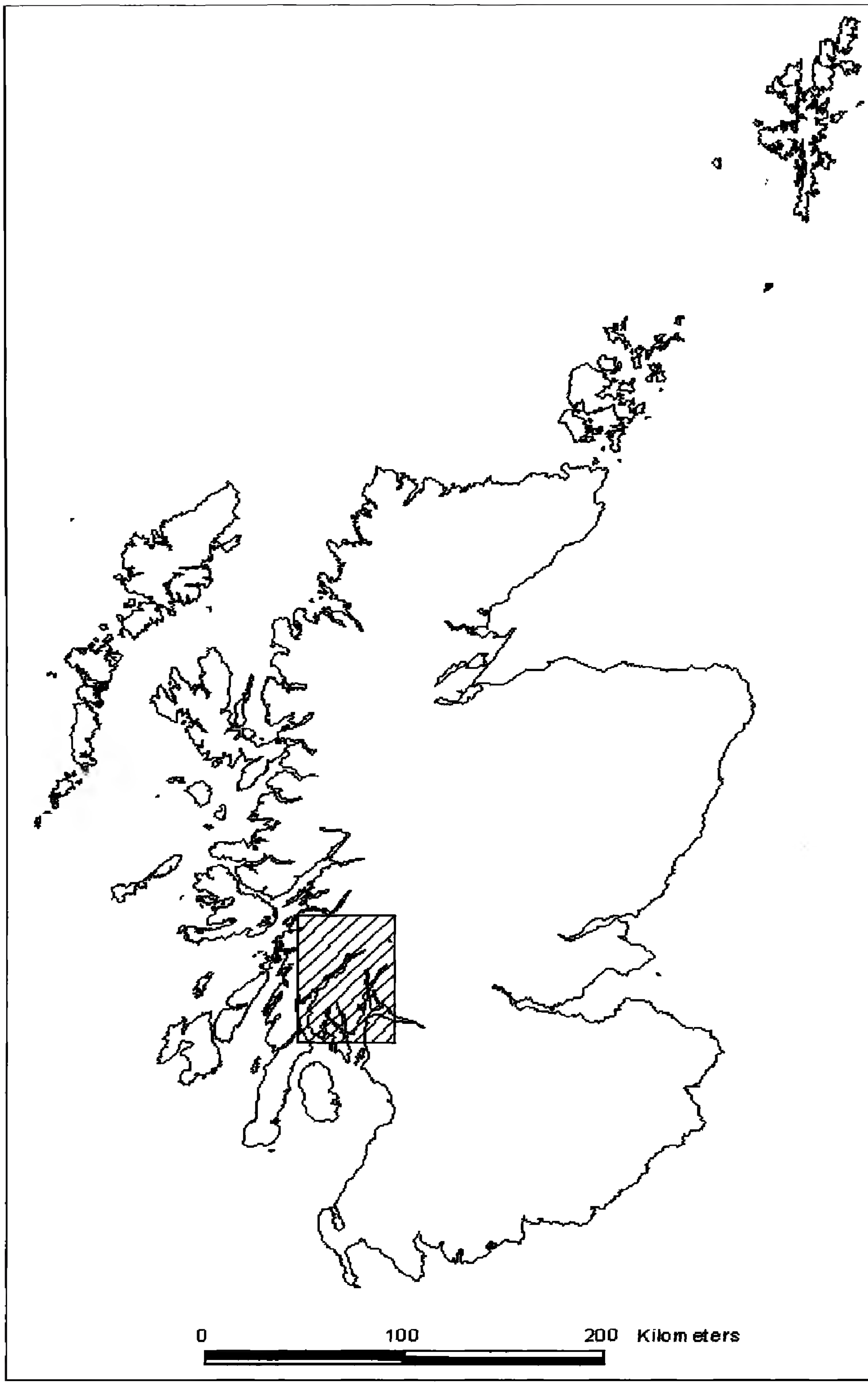

Figure 1. Study area in Argyll, Scotland.

but in the relatively cool climate of the Scottish Highlands thermal updrafts are rare. In a thermal-poor environment, ridges provide upward deflected air where eagles can soar and help determine ranging behavior. Chalmers (1997) demonstrated that Golden Eagles in western Scotland showed significantly positive selection for ridge features in ranging behavior. It is also likely that Golden Ea-

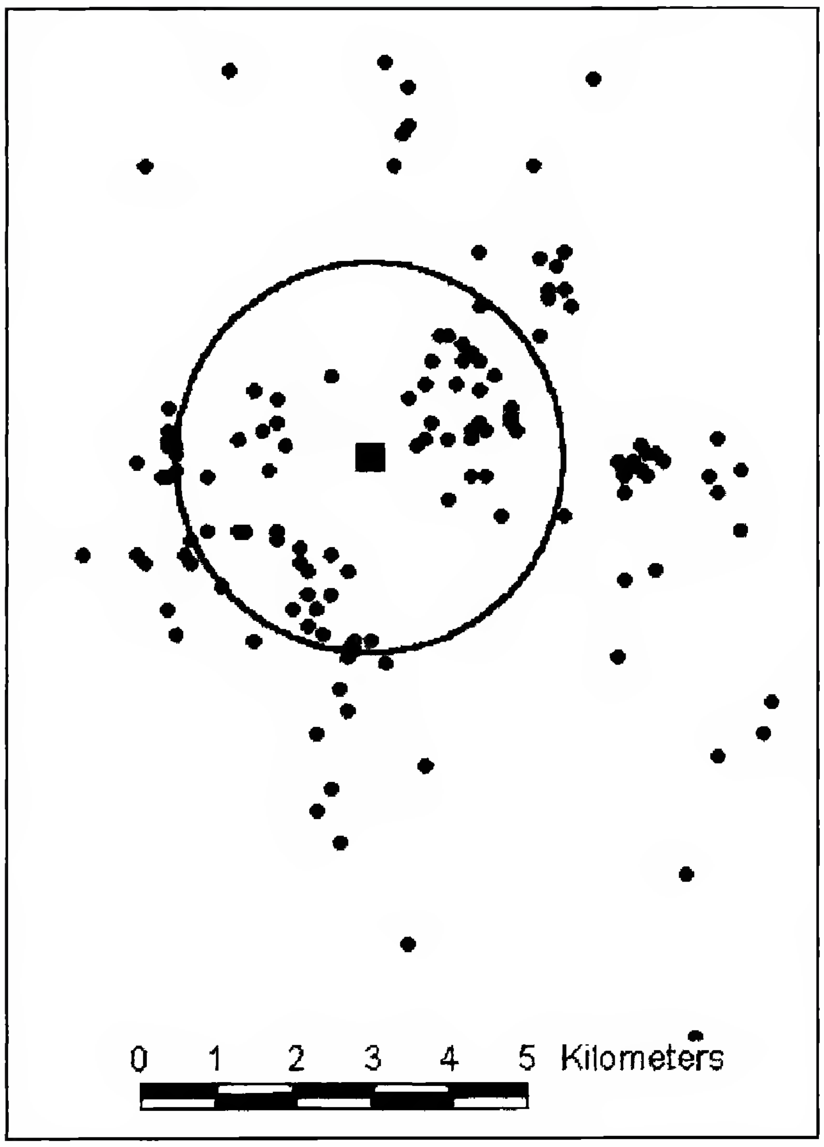

Figure 2. Example of observations of radiotagged Golden Eagles used in the development of the range use model, shown in relation to the estimated range center (square) and a 2.5 km radius about the center.

gles do not favor low elevations both because they are poor in airflow and may be more likely to be centers of potential human disturbance or unsuitable habitat (Watson and Dennis 1992, González et al. 1992). Novel features of the PAT modeling process partially reflected such considerations. These features were incorporation of ground according to coarse distance decay functions in relation to the range center (i.e., a decreasing range of elevations was assumed to be used by eagles with increasing distance from the center) and preferential inclusion of ground close to ridges. The PAT also excluded all elevations below a value derived from the mean and variance that were available within the range being modeled (Watson and Dennis 1992). Golden Eagles prefer certain land cover or habitat types (McGrady et al. 1997), at least in part because of prey availability (Marzluff et al. 1997).

All modeling was undertaken in a raster environment using ArcView Spatial Analyst. Environmental data included terrain (the UK Ordnance Survey, OS) and range center, taken as the mean coordinate for nests used in the past 10 yr.

RANGE USE RELATIVE TO THE CENTER

The range center was calculated and Thiessen polygons were constructed for each range for which we had telemetry data. Concentric annuli, 500 m in width, were circumscribed around the center of each range (i.e., annuli 1 = 0–500 m, annuli 2 = 500–1000 m, etc.). The amount of land available within each annulus was then calculated for each range and then summed for each distance class across all ranges. Ranging data were aggregated for all ranges and the distance to the center was calculated for each data point. Ranging data were assigned to distance categories defined by the annuli and these were aggregated from all ranges. The number of ranging points observed within each annulus, or distance class, was then represented as a proportion of the number that would be expected if all ranging points were randomly distributed according to the land available within each distance class (Fig. 3). Values >1 indicated that observed use was greater than expected and values <1 indicated that observed use was less than expected. Eagles showed an increasing "preference" for areas closer to range centers and increasingly "avoided" areas beyond 2.5–3 km from centers (Fig. 3). The transition from positive to negative use at 2.5–3 km was consistent with the core concept described by McGrady et al. (1997). Eagle use preferences, according to their distance from centers, were used to assign a weighting for each pixel within the Theissen polygon.

USE OF TERRAIN: ELEVATION

The RIN model assumes that all elevations within the core range are exploited by eagles whereas only those >150 m elevation are exploited outside the core (subject to regional modifications) (McGrady et al. 1997). A number of less coarse methods were explored to incorporate local variation in a lower ranging elevation threshold into the PAT. The method that appeared to best match observations calculated the mean and variance of the elevations available within 2.5 km of range centers. It then took a value equal to a single standard deviation below the mean as the lower elevation threshold across the whole range. The PAT as-

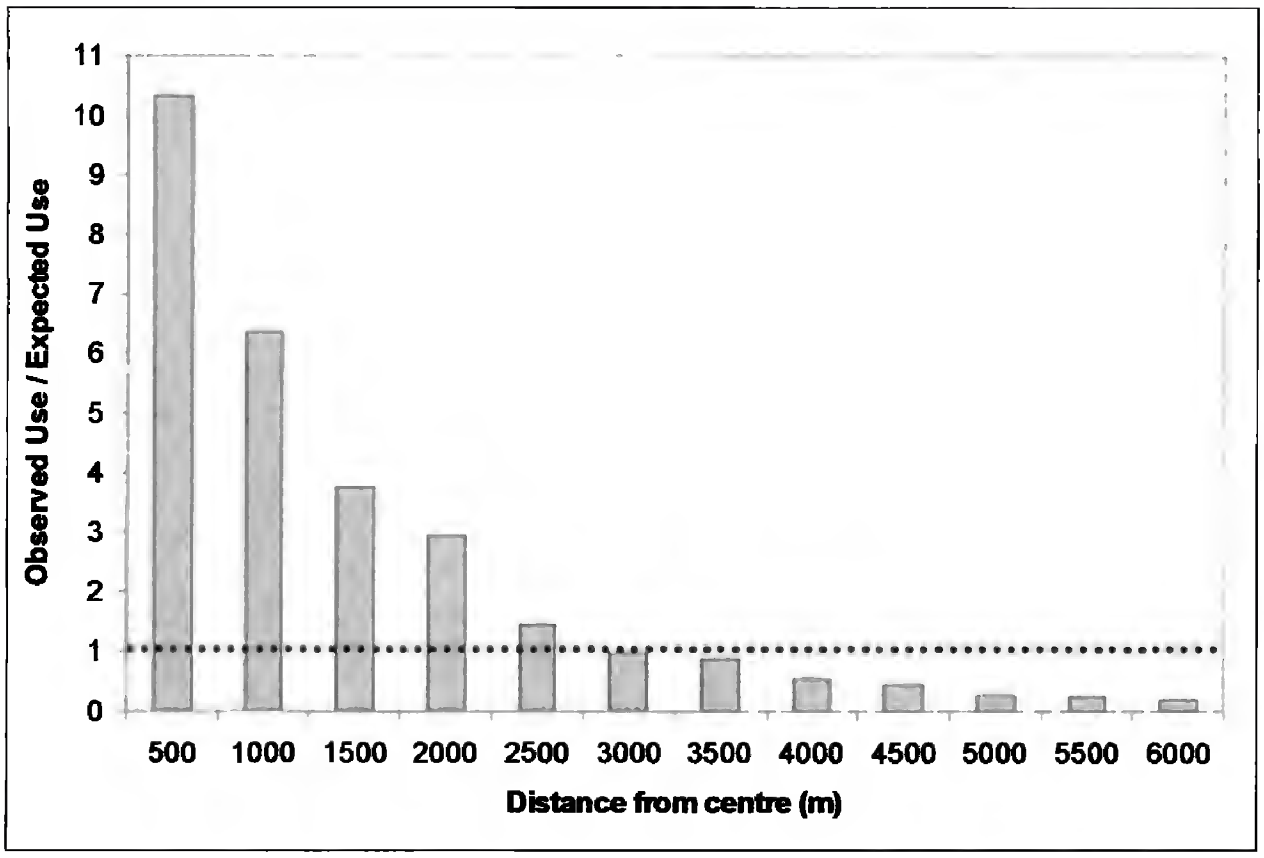

Figure 3. Observed use of range/expected use of range according to distance from the range center for six Golden Eagle ranges in Argyll. Broken line is where observed use equaled expected use.

1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3
0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	3	0
0	0	1	0	0	0	0	0	2	0	0	0	0	0	3	0	0
0	0	0	1	0	0	0	0	2	0	0	0	0	3	0	0	0
0	0	0	0	1	0	0	0	2	0	0	0	3	0	0	0	0
0	0	0	0	0	1	0	0	2	0	0	3	0	0	0	0	0
0	0	0	0	0	0	1	0	2	0	3	0	0	0	0	0	0
0	0	0	0	0	0	0	1	2	3	0	0	0	0	0	0	0
4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4
0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	0	0
0	0	0	0	0	0	3	0	2	0	1	0	0	0	0	0	0
0	0	0	0	0	3	0	0	2	0	0	1	0	0	0	0	0
0	0	0	0	3	0	0	0	2	0	0	0	1	0	0	0	0
0	0	0	3	0	0	0	0	2	0	0	0	0	1	0	0	0
0	0	3	0	0	0	0	0	2	0	0	0	0	0	1	0	0
0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0
3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1

Figure 4. Grid representing individual elevation pixels within the raster GIS, and the process used to determine ridge features. The black square is a source pixel and the four orientations (1–4) in which elevation comparisons were made. If the elevation was lower in all neighbors in any one orientation then the source pixel was classed as a ridge pixel. This process was repeated for all pixels within the range area.

sumes that Golden Eagles do not use areas below this elevation threshold.

USE OF TERRAIN: RIDGES

Ridges can be defined in a number of ways, such as river catchment boundaries, but a method was required that would allow the future incorporation of scale factors, such as distances between ridges, and more qualitative definitions, such as their steepness. In a raster GIS, the method that identified ridges best compared the elevation of each pixel against its neighbors in each of four orientations (NE-SW, N-S, SE-NW, E-W: orientations 1 to 4, respectively, Fig. 4). If the source pixel was higher than all of its neighbors in all directions then it was a local peak; if the source was higher than its neighbors on both sides in at least one orientation then it was classed as a ridge pixel. This process produced some "noise" in the form of isolated "ridge" pixels, but these were filtered out as a post-processing operation to produce defined ridge features.

The vast majority of land was <4 km of a ridge feature and was split into 100 m distance bands from the nearest ridge. The amount of land available within each distance class was then calculated for each range and then summed across ranges and yielded an expected distribution of ranging behavior if it was neutral with respect to ridge fea-

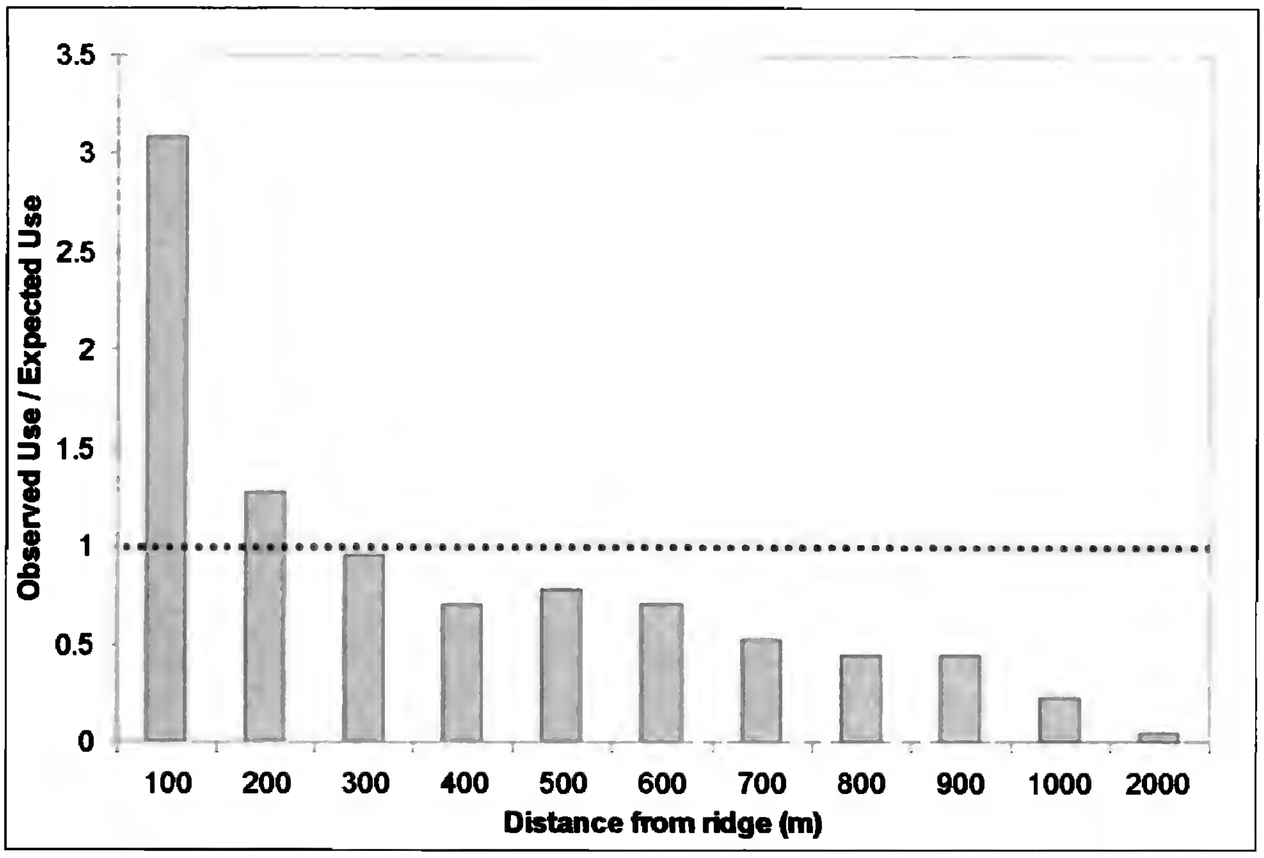

Figure 5. Observed use of range/expected use of range in relation to distance from a ridge feature for six Golden Eagle ranges in Argyll. Broken line is where observed use equaled expected use.

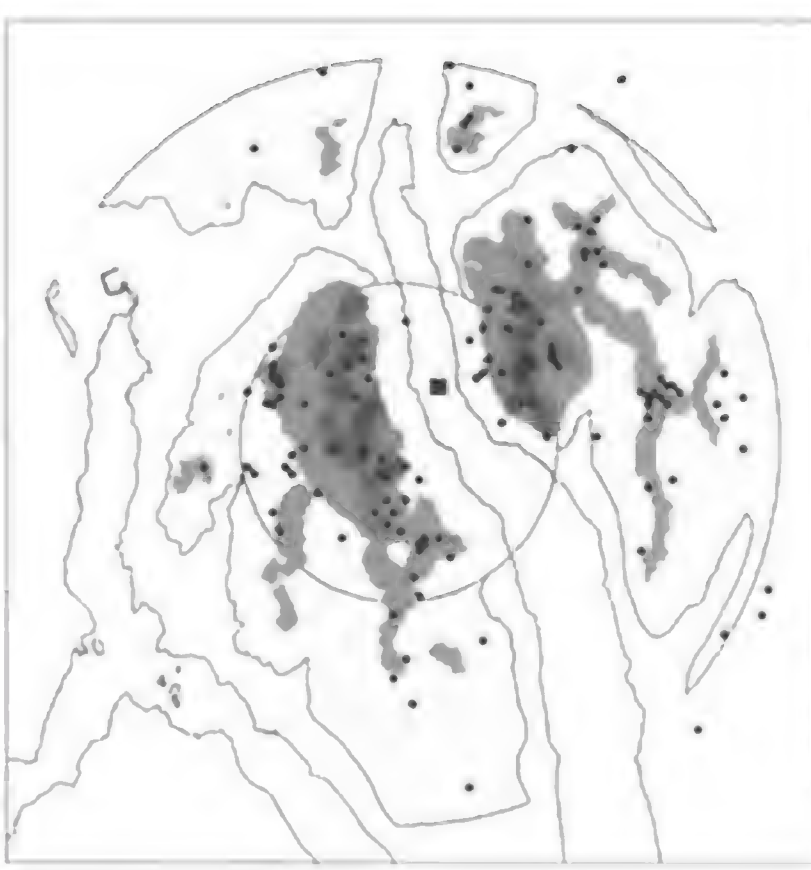

Figure 6. Example of the predicted Golden Eagle range according to the PAT model (darker shading), in relation to observations of actual range use (solid circles), the range center (square), and predicted range according to the RIN model (lighter shading = inner core and outer range boundary).

tures. The number of ranging points in each distance class was then calculated to give an observed distribution of ranging behavior with respect to ridges. The number of ranging points observed within each distance class was represented as a proportion of the number that would be expected if all ranging points were randomly distributed according to the land available within each distance class (Fig. 5). Since values >1 indicated preferential use, it was apparent that Golden Eagles made more use than expected of areas <200 m from a ridge. Eagle preferences, according to distance from a ridge, were incorporated into the model to provide an appropriate weighting for each pixel within the Theissen polygon.

THE PAT MODEL

In the raster GIS with a range center, range boundary and ridge features in place, every pixel had weighting due to its distance to the center and its distance to the nearest ridge. These weightings were added together to give a single probabilistic value for each pixel. Applying the elevation threshold cut-off to all pixels was the final step in the PAT model output (Fig. 6).

For the six ranges in Argyll the fit of the PAT model's predictions to the ranging observations were encouraging and a marked improvement on those of the RIN model (Fig. 6). However, a more

rigorous test would be against ranging observations collected away from the study area.

Future Model Development

The PAT model is a modeling direction, and not a single model. There are a considerable number of future developments to the modeling approach that would be desirable. First is the need to address some of the restrictions inherent in the ranging observations. Behaviors associated with the observations would help to refine the modeling process as Golden Eagles can use different parts of their range for different purposes. Range boundaries, for example, may be visited primarily for territorial display purposes (Watson 1997), and so features that may be important in the rest of the range (e.g., food availability) may be irrelevant in this context. Second, it is important to note that both the RIN and PAT models relate to the nonbreeding season only and Golden Eagle range use can vary with breeding activity (Marzluff et al. 1997, J. Stacey unpubl. data). It is highly likely that the core of the nonbreeding range becomes even more important during the breeding season, but this should be quantified and incorporated into the modeling process. Third, inclusion of land cover information would probably improve the predictive capability of the model, as the radiotagged birds displayed habitat preferences that were probably related to prey availability (McGrady et al. 1997). The apparent predictive success of the PAT model, albeit within a limited set of comparisons, is perhaps surprising without any explicit reference to or surrogate for vegetation type or prey. The preference for ridgelines may nevertheless be at least partly related to prey or habitat availability as well as improved airflow.

Clearly there is a need to examine the model's abilities in a range of other types of Golden Eagle territories and, in all likelihood, adapt it accordingly. A means of recognizing "dead ground" within the modeling environment should be possible and may improve predictions too, given that eagles can exploit such features to surprise their prey (Watson 1997). A more intractable problem may be predicting the use of highly localized and range-specific "honey pot" prey supplies such as rabbit (*Oryctolagus cuniculus*) or seabird colonies. In the absence of any supplementary local information, the best that may be possible under such circumstances would be to exercise additional caution in interpreting model predictions for low-lying or coastal pairs.

The Golden Eagle GIS

The PAT model is one component of a larger GIS application implemented within ArcView and Microsoft Access. It provides a powerful tool for assisting with the management of, and research into, Golden Eagles.

The 1992 National Survey of Golden Eagles (NSGE) (Green 1996) has been entered into an Access database, and includes data on range occupation and breeding success. The Access database has been dynamically connected to ArcView to enable better management, visualization, query, and analysis of these data, as well as ensuring security of the NSGE data. The GIS includes customized and standard research, analysis, and model development capability.

The modeling software allows implementation of range modeling across large areas of Scotland. This facility allows more strategic planning for conservation issues related to Golden Eagles. For example, rather than assessing the impact on Golden Eagles of individual forest planting proposals on a case-by-case basis, as is current practice, areas that are important to Golden Eagles and where there may be conflict with commercial forestry can be predefined across large areas. Similarly, wind farms can potentially pose risks to Golden Eagles (Whitfield 2000). Predefinition of sensitive areas for Golden Eagles will allow their incorporation much earlier into the costly wind farm planning process.

The influence of changes in environmental factors on Golden Eagle numbers and breeding success can be tracked efficiently within the GIS, and when coupled with an ability to model those areas where environmental change is most likely to affect Golden Eagles, it becomes a powerful research tool.

Acknowledgments

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Raptor Research Foundation, Inc., Awards

Recognition for Significant Contributions[1]

The **Dean Amadon Award** recognizes an individual who has made significant contributions in the field of systematics or distribution of raptors. Contact: **Carole Griffiths; E-mail: cgriff@liu.edu.** Deadline: February 15.

The **Tom Cade Award** recognizes an individual who has made significant advances in the area of captive propagation and reintroduction of raptors. Contact: **Dr. Brian Walton, Predatory Bird Research Group, Lower Quarry, University of California, Santa Cruz, CA 95064 U.S.A.** Deadline: August 15.

The **Fran and Frederick Hamerstrom Award** recognizes an individual who has contributed significantly to the understanding of raptor ecology and natural history. Contact: **Dr. David E. Andersen, Department of Fisheries and Wildlife, 200 Hodson Hall, 1980 Folwell Avenue, University of Minnesota, St. Paul, MN 55108 U.S.A.** Deadline: August 15.

Recognition and Travel Assistance

The **James R. Koplin Travel Award** is given to a student who is the senior author of the paper to be presented at the meeting for which travel funds are requested. Contact: **Patricia A. Hall, 5937 E. Abbey Road, Flagstaff, AZ 86004 U.S.A.**

The **William C. Andersen Memorial Award** is given to the student who presents the best paper at the annual Raptor Research Foundation Meeting. Contact: **Ms. Laurie Goodrich, Hawk Mountain Sanctuary, Rural Route 2, Box 191, Kempton, PA 19529-9449 U.S.A.** Deadline: Deadline established for meeting paper abstracts.

Grants[2]

The **Stephen R. Tully Memorial Grant** for $500 is given to support research, management and conservation of raptors, especially to students and amateurs with limited access to alternative funding. Contact: **Dr. Kimberly Titus, Alaska Division of Wildlife Conservation, P.O. Box 20, Douglas, AK 99824 U.S.A.** Deadline: September 10.

The **Leslie Brown Memorial Grant** for $500–$1,000 is given to support research and/or the dissemination of information on raptors, especially to individuals carrying out work in Africa. Contact: **Dr. Jeffrey L. Lincer, 1220 Rosecrans St. #315, San Diego, CA 92106 U.S.A.** Deadline: September 15.

[1] Nominations should include: (1) the name, title and address of both nominee and nominator, (2) the names of three persons qualified to evaluate the nominee's scientific contribution, (3) a brief (one page) summary of the scientific contribution of the nominee.

[2] Send 5 copies of a proposal (≤5 pages) describing the applicant's background, study goals and methods, anticipated budget, and other funding.